# FOREST MANAGEMENT 101

## A handbook to forest management in the North Central Region

This guide is also available online at:

**http://ncrs.fs.fed.us/fmg/nfgm**

**A cooperative project of:**

North Central Research Station

Northeastern Area State & Private Forestry

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# Introduction

Forest Management 101 contains basic information about forest management. It is separated into the six sections: management objectives, socio-economics, ecology, forest health, silviculture, and best management practices. These sections contain information germane to all of the specific tree species guides.

If you have a basic knowledge of forestry, you can skip these sections and proceed to the Specific Tree Species Guides. However, the tree species specific guides also contain links back to this basic forest management information if needed.

# Management Objectives

# Management Objectives

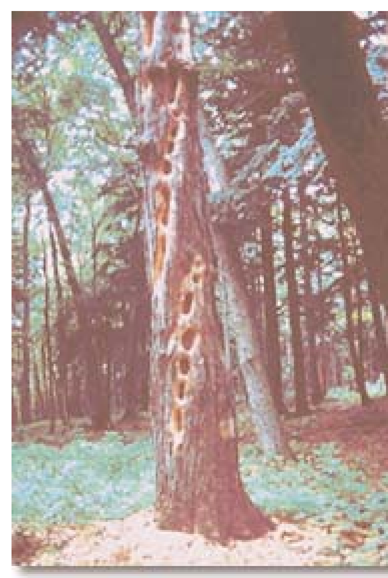
Landowner objectives for properties can vary widely. As examples, some may simply want to enjoy the vegetation as it is, manipulate it to improve wildlife habitat for certain species, derive income from the sale of products, or a combination of these. These objectives illustrate the different ways in which owners may "value" the forest. Regardless, forest vegetation is not static--tree size, value, health, and habitat conditions can change markedly in a decade. The long-term objective of forest management is to achieve the owner's objectives while recognizing the limits of the ecosystem and economics, guidelines or rules for practices, and the dynamics of forest vegetation.

While silviculture (the actual on-the-ground practices used to achieve the management objectives) is applied at the scale of forest stands, it is important to consider the implications of stand management within the context of varying ownership objectives across the landscape. A useful approach for doing this is to consider different intensities of management for the typical objectives of income, habitat improvement, and/or recreation. The actual management used to achieve these objectives may involve similar silvicultural treatments, perhaps varying in their frequency or degree of application.

**Income-focused management** is often associated with high capital investments to ensure rapid dominance by desired species and includes treatments such a precommercial and commercial thinning to maximize growth and pruning to improve the quality of wood. Fertilization, irrigation, site preparation, control of competition, and planting of genetically improved stock are tools used in production management. The establishment and tending of plantations is typically income focused management.

**Sawlogs at landing. Forest County, WI (Terry Strong).**

**Habitat-focused management** is increasingly being applied in North Central forests. Compared to an income focus, this management typically has lower impacts as well as costs and economic returns. The management of aspen to foster young stands that provide favorable ruffed grouse habitat is an example. The management of mixed hardwood stands for diverse forest conditions that favor songbird bird species is another example. In ecological jargon, managing on extended rotations, managing for old growth characteristics, and managing for increased ecological complexity and heterogeneity are similar examples.



**Wildlife tree. Argonne Experimental Forest, Forest County, WI (Terry Strong).**

**Recreation/Aesthetics-focused management** can be either intrusive or non-intrusive in its impacts. When the objective is to protect a natural area from human-caused disturbances, such management is non-intrusive. When the objective is to restore a condition or process, the management applications may be quite intensive. Treatments such as harvesting or fire might be applied to retain early successional species, to create desired structural features, to reduce the threat of insect and disease outbreaks, to control exotic species, or to accelerate the growth of large diameter trees. Intrusive management can also be helpful in developing recreational access, e.g., trails and attractive viewing areas.

When adopting one of these objectives, there are still many choices in silvicultural treatments for a specific forest stand. There are probably more choices than the novice has thought about. First, the choices at any point in time are heavily dependent on the existing stand conditions. Below is a list of some considerations for existing stands :

- Native ecosystem, habitat type, or plant community
- Size or acreage of the stand
- Conditions (upland, lowland, slope, inherent productivity)
- Species composition
- Age of the trees
- Location on the property or in the landscape
- Density of the trees (e.g., stems per acre)
- Access for use, equipment, or security
- Tree size and health and risk
- Availability of markets
- Proximity to neighbors

In practice, stands are typically delineated as forest areas of several to many acres with similar species-tree size-density composition. Stands in the Great Lakes Region are typically 10-40 acres in extent. Given this background, owners may then develop a plan for the stand. A typical management plan consists of the specification of owner objectives, a description of the stand (as above), and a schedule of practices or silvicultural treatments to be applied to achieve the objectives. Common treatments are planting, weeding and cleaning, thinning, harvest, etc. The management plan for an entire property pulls together the individual stand plans and may adjust them in light of nearby stands or overall ownership needs. Importantly, a plan does not have to include harvesting. A landowner may be quite content to allow a forest to grow, mature, undergo replacement, etc. However, various practices including harvesting may be essential to meet other ownership objectives, e.g., to produce large and scenic trees as soon as possible, foster ruffed grouse populations, or produce income. The income can also pay for these practices. Importantly, active management can greatly speed the achievement of objectives, limit undesirable conditions that might develop (e.g., accumulation of forest fire fuel loads), and increase outputs such as wildlife numbers or amounts and quality of saleable forest products.

# Economic Considerations

# Economic Considerations

Whether its stocks, bonds, mutual funds, or savings accounts, as an investor you are interested in getting the greatest return on each dollar invested. Forest land is no exception. Many landowners, however, overlook the potential opportunity to increase the return on their forest land investment. In addition to providing important wildlife, recreation, and aesthetic values, investing in forest management can add to your forest's bottom line. Because management is a long-term proposition, the investments you make need to be carefully considered. When properly applied, modest investments in management early in a life of a forest stand can have a substantial impact on financial returns through increased forest growth, improved wood quality, and greater economic yields in the future. In addition, investing in forest management often compliments many other reasons individuals own forests such as improving wildlife habitat.

While forest management investments are, by their very nature, site specific, the cumulative impact of making these investments across a large forest area can be substantial, both economically and ecologically. Economically, investments in forest management repeatedly made across large areas can significantly increase the area's forest productivity and yield. In addition to providing a higher return on an owner's investment in forest land, significant investments in productivity have the potential to increase regional economic activity. Ecologically, increasing regional forest productivity through forest management means the same volume of wood can be produced from a smaller land base, enabling greater acreage to be used for non-economic purposes.

There are a number of factors to consider when making an investment in forest land management. These include:

**Tolerance for risk -** Due to the long-term nature of forest land management, investing in forest management often carries with it a large degree of uncertainty that an anticipated return on the investment will be fully realized. This includes uncertainty about future prices for your products (e.g., What markets will exist when my products are ready for sale?), management costs (e.g., What will be my annual property tax liability for the property?), and future forest conditions (e.g., Will forest growth increase in response to management as expected? Will the forest be susceptible to insect or disease infestation or wildfire?).

**Investment timelines -** Landowners need to consider the timeframe associated with many forest management investments. These investments may not be realized for years or even decades. In some cases, it may be your heirs that realize the investments you make today in your forests.

**Portfolio diversification -** For many individuals, investing in forest land management provides added diversification that compliments an existing investment portfolio.

**Stand and ownership analysis for potential practices -** The existing conditions of your forest (e.g., tree types, sizes, ages) will often dictate the opportunities to invest in forest management, as well as the specific practices that can be applied.

**Financing -** Depending on the access you have to capital to fund your investment in forest management, you may need to secure outside funding. The terms of outside financing (i.e., the interest rate charged by the lending institution, repayment period, amount of the investment financed) can vary considerably and have substantial impact the financial feasibility of the investment.

**When to sell your products -** How will you know when your timber and other forest products are ready for harvest? What criteria will you use to make this determination? From a strictly financial perspective, you will want to sell your products when they no longer increase in value at a rate that exceeds your next best investment opportunity (e.g., your opportunity cost). For example, if you could invest the proceeds from the sale of your forest products into an account earning an eight percent annual return, you would want to let your forest grow until its value increases at a rate that is less than eight percent per year.

**Marketing -** When your forest products are ready for sale, there will likely be costs associated with preparing your stand for sale and finding a market for the products. Many landowners use consulting foresters to oversee the sale of forest products, who typically collect a fee that represents a percent of the gross sale value.

**Taxes -** Property taxes are usually the single largest recurring annual cost of forest land management. What are the expectations about the future level of property taxes? Additionally, how will federal and state income tax provisions (e.g., treatment of timber income and management expenses) affect the performance of my investment?

**Record keeping -** Important, but often overlooked is keeping complete and detailed records of your forest management activities. These records are not only important for tax purposes, but they also enable you to better document the timing and types of treatments applied to your stand.

**Government and other support or incentive programs -** There are several government-sponsored programs that provide technical and/or financial assistance to forest landowners interested in making investments in forest land management. This includes cost-share funds to help with certain management practices such as tree planting or other silvicultural activities. A consulting forester or your local DNR office can help you identify the programs applicable for your forest management needs.

### *Key Economic Concepts*

**Time value of money -** Financial analyses compare investment costs to expected returns. When these costs and returns are realized at different points in time, adjustments need to be made so the two can be correctly compared. Consider a simple project that consists of an investment cost of $100 and produces a return also equaling $100. If the project's cost and return occurred at the same time you would be indifferent about the whether to undertake the project. The $100 cost completely offsets the $100 revenue, leaving you with a net gain of $0. However, if the $100 return wasn't realized for five years, you probably wouldn't want to undertake the project. Why? If you invested that $100 in a savings account earning 3 percent annual interest, your account would be worth almost $116 after five years - considerably more than the $100 return expected from the project. When you take the earning power of your investment costs into account, it quickly becomes apparent that time does matter when it comes to analyzing investment opportunities.

The long period of time it takes to grow a forest means many investments in forest management that are made today often aren't going to be fully realized for many years (possibly decades) into the future. Even though the projected revenue from selling your timber in the future might look substantial, keep in mind what your investment could've earned if it had been invested elsewhere during the time your forest is growing. To correctly compare future returns from forest management to the cost of forest management investments, one has to consider how much your initial investment would have grown in value had it been invested elsewhere.

**Opportunity cost -** Opportunity cost is the value of a foregone opportunity. For example, if you had $100 that you did not plan to spend for the foreseeable future and had the option of: a) keeping the $100 in your wallet; b) investing the $100 in a bank account and earn 2 percent interest, or c) purchasing a savings bond that earned 4 percent interest annually, you'd likely buy the savings bond. The opportunity cost of buying that savings bond is the value of next best opportunity that was not taken. In this case, it's earning 2 percent in a bank account.

Opportunity cost is an important consideration in analyzing any potential investments in forest management. By investing your time and financial resources (i.e., money) in forest management, you are not able to use these resources elsewhere. Financial and economic analyses use terms like "discount rate" or "interest rate" to represent the opportunity cost of undertaking a project. For example, a landowner's opportunity cost of investing in forest management may be the return that could be realized if these resources were invested in the stock market…the next best investment opportunity. For another landowner, the alternative to forest management investment may be quit different such as a savings account. Depending on the value placed on an individual's time and financial resources and tolerance for risk, the opportunity costs for a given project can vary considerably among individuals. Consequently, an analysis of the same project can produce very different results if different discount rates are used. It is important that when analyzing forest management investments, you take into account the true cost of your time and resources. Don't assume these costs will necessarily be the same for you as they are for your neighbor - they depend on your individual circumstances.

**Economic decision rules -** Many economic decision rules are used to analyze the financial feasibility of investment opportunities. The more common ones that are used in financial analyses include: benefit-cost ratio (B/C), a ratio of discounted project benefits to discounted project costs; internal rate of return (IRR), the rate of return on a project's investment; and net present value (NPV), the difference between a project's discounted benefits and discounted costs. Projects are considered financially sound if the B/C is greater than one, the IRR is greater than the rate of return that would be generated if the investment was made in the next best investment alternative to the project (i.e., the project's opportunity cost), and the NPV is positive.

While no single economic decision rule is perfect, the one that is the most reliable and widely accepted is NPV. NPV is a straightforward measure of a project's financial attractiveness. It's also easy to understand. A positive NPV indicates that a project is a better use of your resources when compared to the rate of return you could get from your next best investment opportunity.

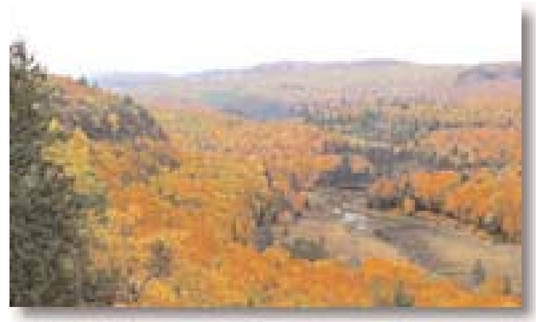
For example, if a landowner needs to earn an 8 percent return on an investment in forest management, all future returns and costs associated with this investment would be discounted back to present day terms (e.g., a $108 return or cost next year is only worth $100 today using an 8 percent discount rate). After discounting all of the project's returns and costs back to present day values, these discounted costs and benefits are summed. The sum of all discounted returns less discounted costs is the project's NPV. If the project's NPV is positive (the discounted benefits exceed the discounted costs), then the project is worth undertaking based solely on its financial performance.

It's also important to keep in mind what NPV doesn't indicate. NPV doesn't say anything about the size of the investment that is needed for a project, the timing of costs and benefits over the life of a project, or how long a project will last. It also doesn't take into account any project costs or benefits that can't be quantified in monetary terms.

**Assumptions -** The results of any economic analysis are heavily influenced by the assumptions that are made about the project being considered. In analyzing the financial attractiveness of an investment in forest management, a number of important assumptions need to be considered. These include assumptions about future timber prices, forest management costs, rates of tree growth, property taxes and insurance costs, inflation, and interest rates. While no one can predict with complete certainty these factors, steps can be taken to increase the likelihood your assumptions are "in the ball park". This includes using only sources that are known for providing objective and reliable information, consulting more than one source to determine how greatly the factors you are considering can vary from one source to another, and reviewing existing financial analyses of forest management investments. Government and university publications, professional consulting services, and economic and market reviews are good starting points. Additionally, the Internet provides access to many sources of useful information that, until recently, were not widely distributed or known.

# Ecology

# Ecology



**Wildlife tree. Argonne Experimental Forest, Forest County, WI (Terry Strong).**

Forest management may be viewed as applied forest ecology. Trees and other vegetation in a stand are managed in ways that reflect and capitalize on the ecological capabilities and tolerances of different species and ecosystems. Forest sites are managed to utilize and sustain their productive capacity and in ways that recognize the ecological association between survival and growth of different trees and site characteristics. Management practices often reflect an understanding of the ecological responses of forests to disturbance events that remove trees or other vegetation.

This section highlights ecological characteristics of forests and forest vegetation in many ways, as well as ecological aspects of forest management. In Forest Management 101, we provide general introductory material on the history of forests in the Great Lakes region and the importance of site, species, and disturbance regimes when formulating management examples and prescriptions.

Within guides on specific tree species, we provide more detail on ecological characteristics of that species, the sites where it occurs, and characteristic natural disturbance regimes. Moreover, we provide information needed to develop management approaches that focus on the ecology of that species and associated sites. Finally, much of the information on silviculture and forest health involves important ecological insight needed to manage the species effectively.

Foresters often refer to ecological information related to individual tree species as the Silvical characteristics of a tree. The silvics of almost all tree species in North America are described in detail in a Forest Service publication titled, "Silvics of North America." This basic Silvical information is vital in the management of all North American tree species.

### *Historical ecology of the upper midwest*

Historically, the regional landscape of the upper mid-west, largely Minnesota, Michigan, and Wisconsin, has been dominated by forest cover. Since retreat of the last continental ice sheet, approximately 11,000 years ago, various types of forests have developed according to climate, site capabilities, and natural and man made disturbance regimes.

Prior to Euro-American settlement, which began in earnest in the early 1800's, the predominant forest types in the region included upland boreal conifer forests, lowland conifer swamps, jack pine and red pine barrens and forests, mixed red and eastern white pine forests, oak-pine forests and oak savannas, mesic northern hardwoods, oak-hickory forests, deciduous wetlands, and aspen-birch forests. Most of these types persist today, although in vastly changed acreages. In particular, the aspen-birch type has greatly expanded at the expense of pine and oak-pine types.

**Disturbance Dynamics and Human History -** The increase in aspen at the expense of pine reflects a changing landscape disturbance dynamic. Importantly, regional natural disturbances prior to Euro-American settlement, included fire, wind, insects and to a lesser extent, pathogens, ice storms, and floods. Fire in particular was key to shaping the type and distribution of forest ecosystems across the regional landscape. Jack pine forests were maintained by frequent stand replacing fires, mixed-pine forests experienced

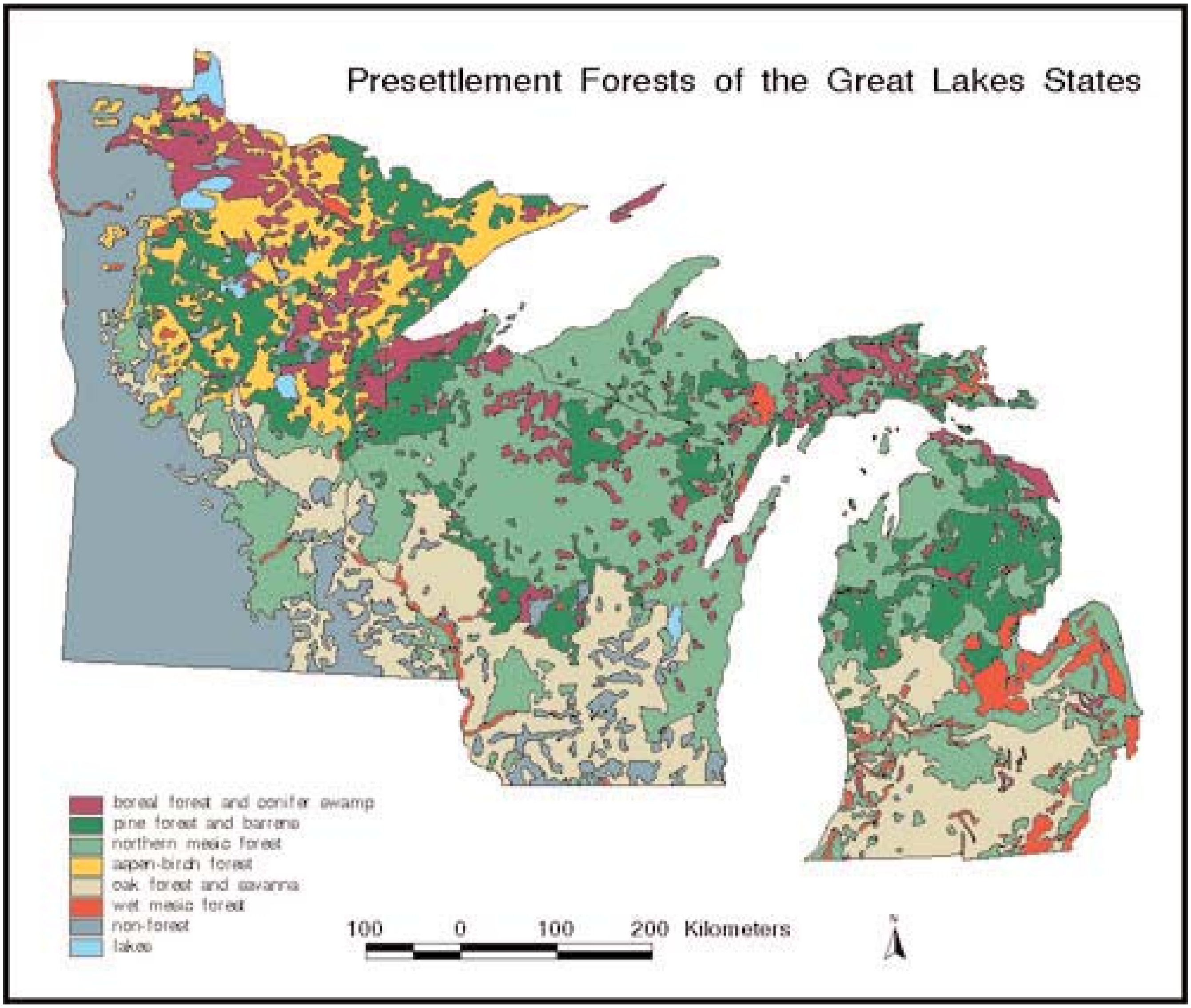



**Figure 1. Presettlement vegetation map of the western Great Lakes region.**[1]

1 Stearns, Forest W. 1997. History of the Lake States Forests: Natural and human impacts. In: Vasievich, J. Michael; Webster, Henry H., eds. Lake States Regional Forest Resources Assessment: Technical Papers. Gen. Tech. Rep. NC-189. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 8-29.

frequent (stand-maintaining) surface fires and infrequent stand-replacement fires. Boreal conifer forests burned regularly, as did oak and pine savannas. In contrast, deciduous wetland and northern hardwood forest were largely resistant to burning, except during extreme, prolonged drought conditions. Native Americans also used fire as a tool for vegetation management over local to large areas.

This landscape fire regime was altered drastically by logging of the primary forest and Euro-American settlement that followed. After logging and land clearing for agriculture, slash-fueled wildfires burned through much of the region, particularly on dryer sites. In many cases this eliminated advance regeneration and local seed sources of pines. Fire suppression followed, allowing expansion of aspens, and to a lesser extent paper birch, on sites formerly dominated by pine types. The decline of agriculture, primarily in the north, also lead to aspen and hardwoods invading and reclaiming many old fields.

**Contemporary Landscape Conditions -** Forest management, including harvesting, site conversion, and planting, has replaced fire as the primary driver of forest dynamics in the region. Aspens are widely utilized commercially, are easily regenerated vegetatively after logging and, as such, forests dominated by aspens are still a prominent feature in the contemporary landscape. Northern hardwoods are still abundant in the region and important commercially in various locations, however, the composition of these systems has shifted from fairly species rich tree communities to largely sugar maple dominated.

**Early logging in Wisconsin.**

Upland conifers including white spruce are important economically, and in some areas productive northern hardwood sites have been converted to white spruce. Lowland conifers are utilized commercially and the economic importance of these forest types will remain well into the future. Acreages of pine types, especially eastern white and red pines, have been drastically reduced, but there is growing interest in increasing the presence of these species and their respective forest types in the region.

**Second growth Sugar Maples. Argonne Experimental Forest, Forest County, WI. (Terry Strong)**

### *Key ecological concepts*

Effective forest management and silviculture are intimately linked to an understanding and appreciation of forest ecology. Understanding the biophysical characteristics of forests and forest sites, the silvics or autecology of various tree and plant species, and the relationship of disturbances to forest development are central to developing effective management plans and making reasonable predictions about future conditions of a forest.

**Site characteristics -** A fundamental need when considering management options for a stand is to consider the relationship between forest site quality, that is its soil and topographic characteristics, and the species of trees that can grow best on that site. Although not without exceptions, there is a strong relationship between key measures of site quality, such as soil moisture and nutrient availability, and the type of tree species that naturally occur on that site. For example, pines tend to occur on soils that are dryer and less nutrient rich than many northern hardwood species. The latter tend to occur on soils that are moist (mesic), nutrient rich, and loamy textured. Some early successional species, such as aspen, occur across a wide range of site conditions. Most species of trees will grow best on mesic, nutrient rich sites, regardless of where they occur naturally. However, if they are not native to a particular type of site, it may take a significant management effort to allow them to establish and maintain dominance on a site. For instance, red pine and white spruce have desirable growth rates when established on northern hardwood sites, but it takes a significant economic investment in site preparation and herbicides to allow them to achieve and maintain dominance in the face of competition from species native to the site. See Table 1 on the next page.

**Species characteristics -** Understanding ecological characteristics of plant species is important when considering management objectives. Differences in growth rates will help to determine the amount of effort that might be needed to establish and maintain particular species on a site, even ones that are native to that site. For example, root suckers of bigtooth and trembling aspen have higher early height growth rates

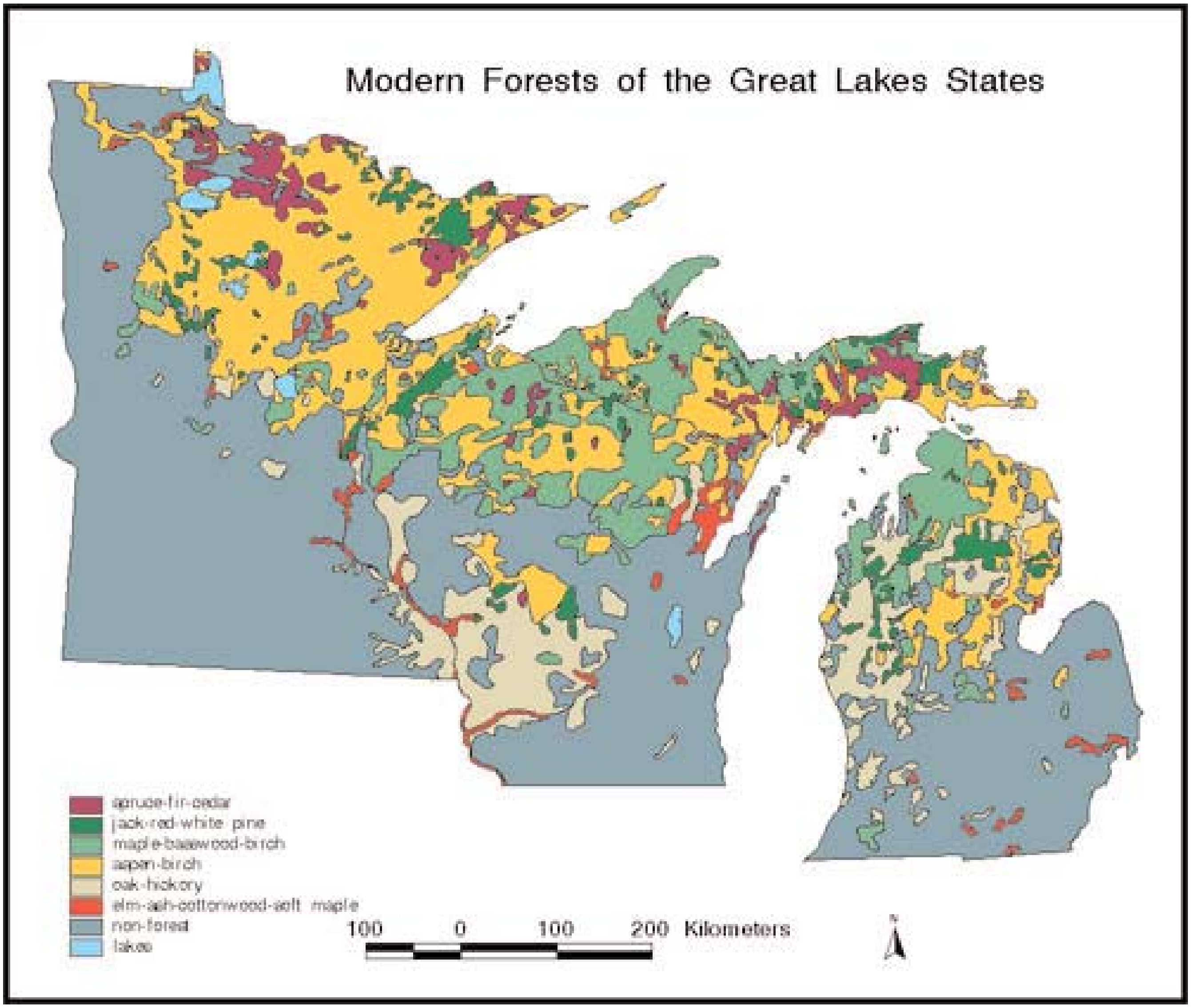



**Figure 2. Contemporary forest of the western Great Lakes region.**[1]

and both species tend to regenerate from suckers at high initial densities, ensuring that aspen will take control of a site soon after a harvest. On the other hand, establishing a slower growing species like red pine may require several years of competition control investments to keep early successional shrubs such as hazel or raspberry from dominating the site.

Species characteristics are also important from the standpoint of managing for wildlife habitat and more broadly, for the diversity of plants and animals that may occur in the forest. For instance, hard mast producing species, such as oaks, are favored by many species of birds and small mammals. So insuring that oaks are present in your forest, if the site is conducive to growing them, may be an important consideration.

1 Stearns, Forest W. 1997. History of the Lake States Forests: Natural and human impacts. In: Vasievich, J. Michael; Webster, Henry H., eds. Lake States Regional Forest Resources Assessment: Technical Papers. Gen. Tech. Rep. NC-189. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 8-29.

Tree species can change the characteristics of the site on which they occur. For example, the needle litter of conifers such as red pine are acidic and over time, can reduce the pH of the soil and the availability of certain nutrients. This may be a consideration when converting a site to a species that does not typically grow there, such as the earlier example of a northern hardwood site converted to red pine.

**Three-mile Island blowdown (E. Sagor)**

**Natural disturbance -** Forests are complex and dynamic systems that change in response to disturbances of various types and intensities. Understanding the response of tree species to disturbance is a key to effective forest management. In general, small canopy disturbances, such as removal of a single large canopy tree through selective harvest or perhaps from natural windthrow, will provide opportunities for neighboring trees to grow laterally, but little opportunity for new generation to develop. As opening size increases, again either naturally from a major disturbance or through more harvesting, the probability of new regeneration establishing increases, along with increasing growth of remaining trees. How the forest floor and mineral soil is disturbed will also influence composition of the developing forest. Opening of the canopy along with ample mineral soil exposure will favor establishment of certain species of plants that require less competition in the understory or respond favorably to high soil temperatures. The combination of canopy disturbance and mineral soil exposure can result from natural surface fires that occasionally spread through tree crowns and kill overstory trees, or a windstorm that uproots a number of trees in a patch, or from harvesting that also exposes mineral soil.

**Stand characteristics -** There are certain descriptors of stand structure that you should understand when reading material in the guides and when considering choices among management practices.

Age structure is a description of the predominant tree age characteristics of the stand. Common categories used to describe age structure include:

**Even-aged -** most of the main canopy trees are of one age-class. In natural stands these trees are rarely all the same age, as would be true in plantations. Rather, a stand is said to be even-aged if the main canopy trees all established within a period that is no more than 20% of the typical life span of the species being considered. As the stand develops, new trees may establish in the understory, but until these start to grow into the canopy, the stand is still generally considered even-aged.

**Two-aged -** most of the main canopy trees are of two distinct age groups. This might occur if part of the stand was harvested or killed by a natural disturbance, leaving many remnant trees, followed by regeneration of a new group (cohort) of trees.

**Uneven-aged -** these stands are composed of more than two distinct age groups. Rarely are they truly all-aged, but rather the distinct age groups (cohorts) are established in response to some past disturbance that left some trees but also provided opportunities for new regeneration over several to many decades.

Composition generally is used to describe the species of trees that occur in the stand, for example, red pine or oak. Stands composed of largely one dominant species are said to be mono-specific. Stands composed of two or more species are said to be mixed-species stands. Stand composition can be described more broadly to include description of other vegetation layers, such as red pine with a hazel understory.

**Table 1: Relative growth potential for major tree species across habitat type groups (only those habitat types where the species occurs naturally are considered).[1]**

| | | | |
|---|---|---|---|
| Very good | Good | Fair | Poor |

| | Very dry-dry | Dry-dry mesic | Dry mesic | Mesic | Mesic-wet mesic | Wet mesic-Wet |
|---|---|---|---|---|---|---|
| Sugar maple | | | Good | Very good | Good | |
| American Beech | | | Poor | Very good | Good | |
| Hemlock | | | Poor | Very good | Very good | Fair |
| Balsam fir | | Fair | Good | Very good | Very good | Fair |
| White cedar | | | | Very good | Very good | Good |
| Basswood | | | Fair | Very good | Very good | Fair |
| Red maple | Poor | Fair | Good | Very good | Very good | Very good |
| Yellow birch | | | Poor | Very good | Very good | Good |
| White ash | | | Good | Very good | Very good | Good |
| Black ash | | | | Very good | Very good | Very good |
| White spruce | Poor | Fair | Good | Very good | Very good | Good |
| White pine | Fair | Good | Very good | Very good | Very good | Good |
| Red oak | Poor | Fair | Good | Very good | Good | Fair |
| White birch | Poor | Good | Good | Very good | Good | |
| Aspen | Poor | Good | Very good | Very good | Very good | Good |
| Red pine | Good | Very good | Very good | | | |
| Jack pine | Good | Very good | Very good | | | |
| Pin/Black oak | Fair | Very good | Very good | | | |

1 From: Kotar, J., Kovach, J., Burger, T., 1999. University of Wisconsin-Madison. Field Guide: Forest Habitat Types of Northern Wisconsin.

**Large Dead Wood**, which until recently was referred to as coarse woody debris, includes snags (standing dead trees) and dead trees and large branches on the forest floor. Trees die naturally in any forest for a variety of reasons. This occurrence, in small to moderate numbers, is not indicative of any particular health concern. In fact, dead wood in the forest provides habitat and food resources for many different species, including small mammals, birds, insects, fungi, and some plants.

**Spore structures of pine needle rust on red pine needles. (S. Katovich)**

**Vertical structure** refers to the types and distribution of different vegetation layers, from the ground to the top of the canopy. Vegetation layers in most forest stands, at some point in their development, will include canopy trees, subcanopy trees, woody shrubs, and groundlayer vegetation (including tree and shrub seedlings, herbs, and mosses). Additionally, different species of canopy trees (in mixed-species stands) will often form stratified layers with the crowns of faster growing (or older) species rising above the crowns of slower growing (or younger) species.

**Horizontal structure** refers to the horizontal spatial distribution of trees, other vegetation, and large dead wood across a stand. On one extreme, even-aged plantations have uniform horizontal structure, with an even distribution of trees, canopy cover, understory vegetation, and forest floor conditions. At the other extreme, an old-growth northern hardwood forest that experiences regular small-scale canopy disturbances from tree blowdown, has a high degree of spatial heterogeneity in structure and composition. Some areas in the stand that develop in new canopy gaps, perhaps with exposed mineral soil from uprooted trees, will have abundant herbaceous and shrub vegetation. Other areas in the stand will be dominated by closed canopy conditions, a thick litter layer and few understory plants. The point is that in a plantation horizontal structure will likely be relatively homogeneous across the stand. Conversely, in the old-growth forest, horizontal structure will likely be heterogeneous across the stand. Between these two endpoints, horizontal structure may vary widely depending on stand age, composition, and disturbance and management history.

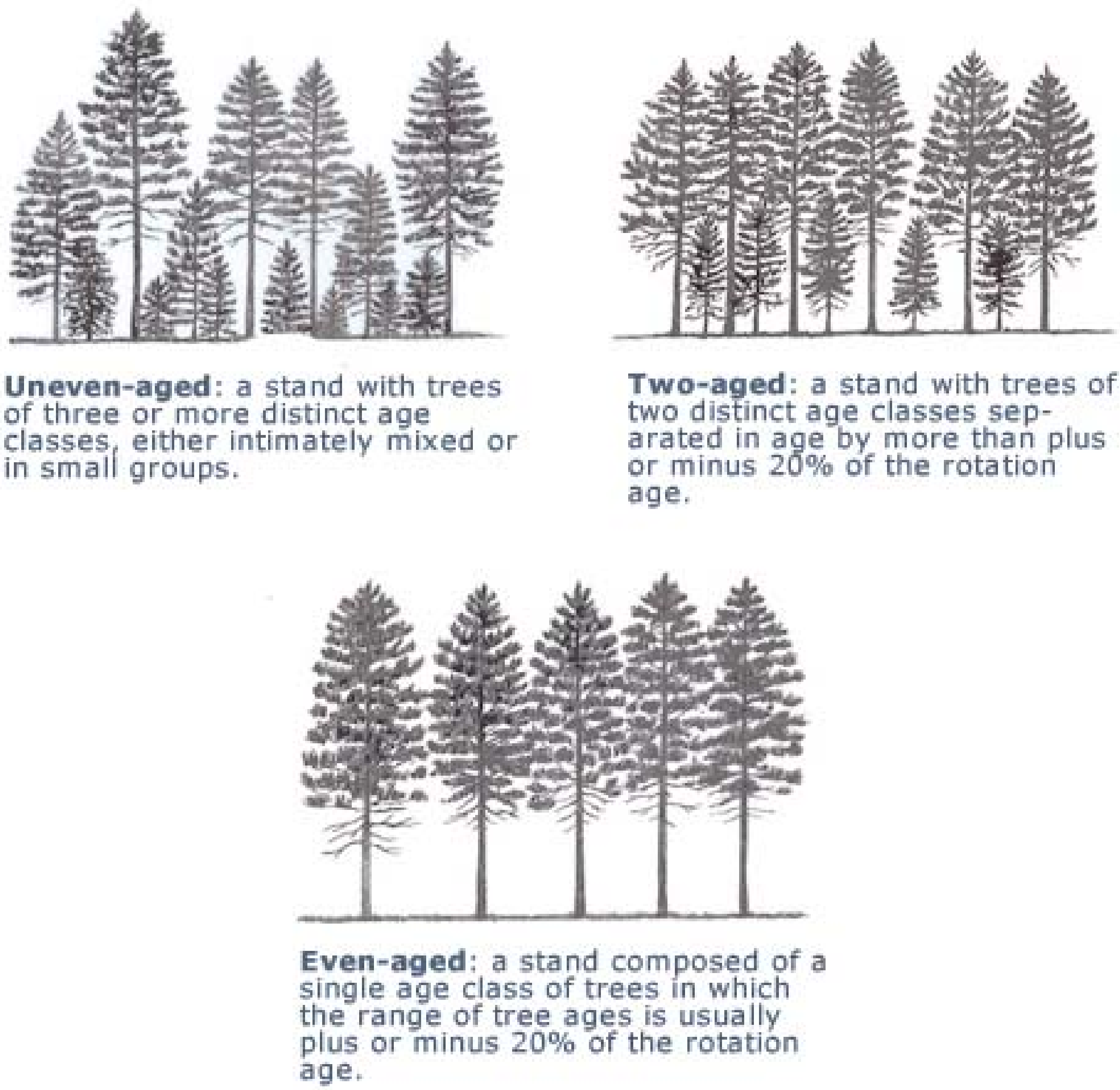



**Figure 1. Types of stand age structure (Definitions from: Helms, John A. 1998. Dictionary of Forestry.)**

# Forest Health

# Forest Health

Many events can impact the health of individual trees, stands of trees, and even entire forested landscapes. These can include insect and disease outbreaks, damage from animals such as deer, and weather events such as droughts, hail storms, wind and ice storms. Many of these events are unpredictable, especially the weather events. Others, such as relatively cyclic insect outbreaks should be expected. Their occurrence raises concerns with forest managers and landowners. However, in the majority of cases, the long-term damage that results is small. The presence of some dead and dying trees may be viewed in a positive perspective as these trees provide valuable habitat for wildlife species and increase the diversity of life in a forest stand. Sometimes however, the damage from an insect or disease outbreak or other event can limit the ability to achieve a given management objective. In these cases, management practices may be available to suppress or mitigate the problem. Pro-active approaches may also be implemented well before potential problems surface thus avoiding or mitigating them. In many cases it is simply a matter of avoiding inherently risky management approaches. The tree species specific guides that follow highlight the pro-active approaches as well as the risky practices that may actually foster pest problems.

Tree and forest health information is available in several different formats within the tree species specific management guides. First, for each tree species, a section titled "Specific Pest Concerns" is available. In that section you will find information on the major insects and diseases, important mammal problems and weather related concerns. Second, a section titled "Pest Problems and Stand Development" is available. This section points out what pest problems are likely to impact stands at different stages of development, from seedling to old-growth. Third, forest health material and specific recommendations are integrated into various sections of the guides themselves. In many cases this is done using warnings that indicate certain pest concerns exist. Numerous photographs and links are available to assist in identification and to provide more detailed management information.

# Silviculture

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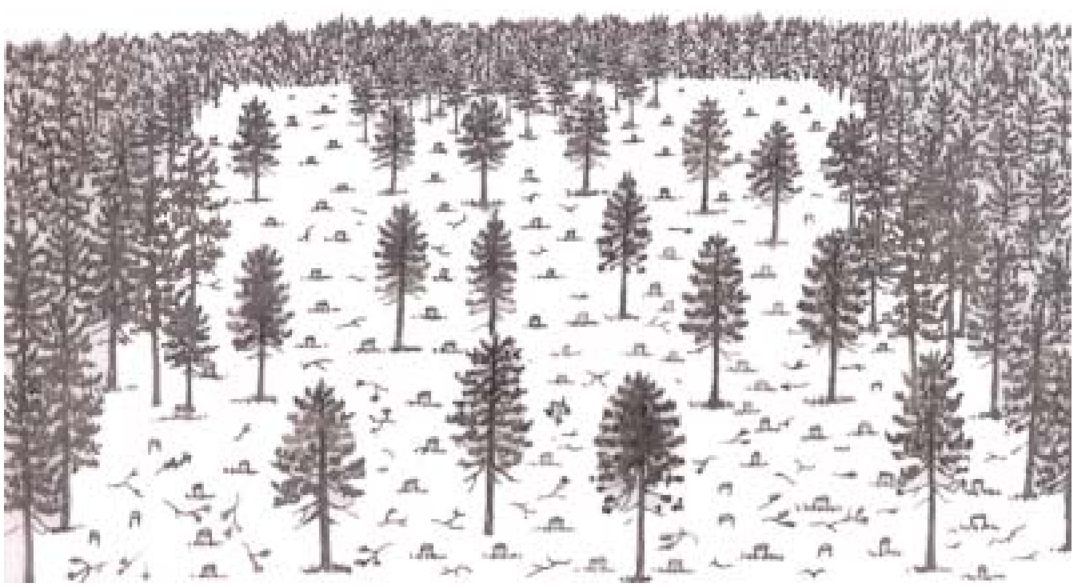
The key to effective forest management planning is determining a silvicultural system. A silvicultural system is the collection of treatments to be applied over the life of a stand. These systems are typically described by the method of harvest and regeneration employed.

In general these systems are:

**Clearcutting -** The entire stand is cut at one time and naturally or artificially regenerate.

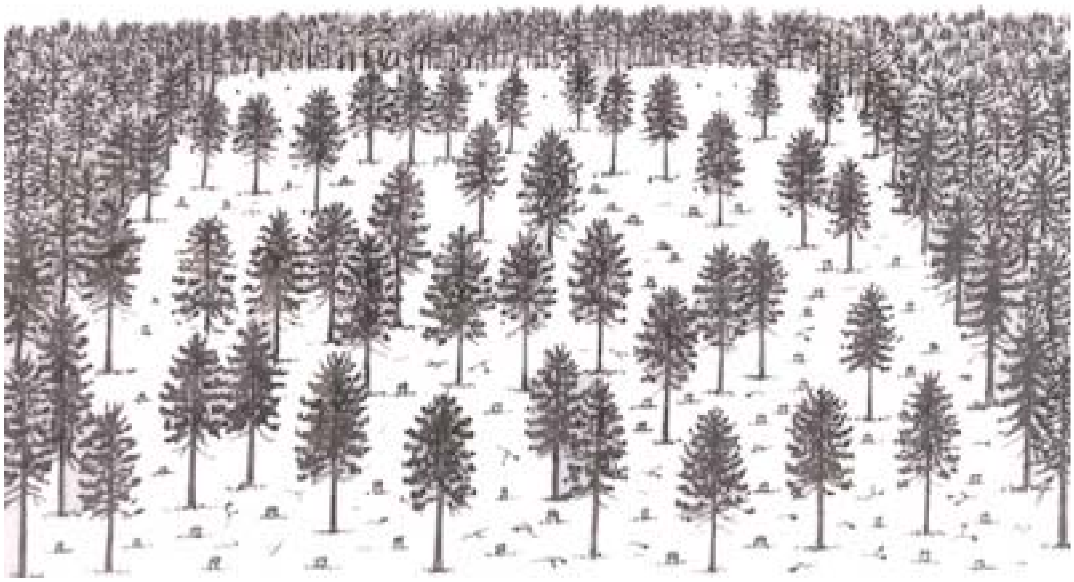
**Clearcutting**

**Seed-tree -** Like clearcutting, but with some larger or mature trees left to provide seed for establishing a new stand. Seed trees may be removed at a later date.



**Seed-tree**

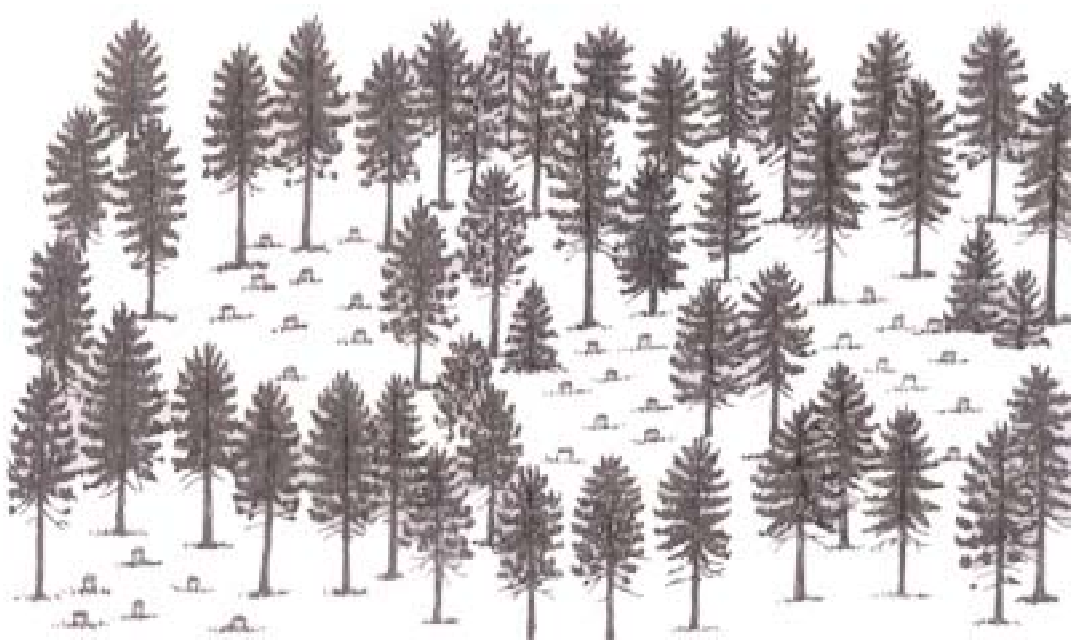
**Shelterwood** - Partial harvesting that allows new stems to grow up under an overstory of maturing trees. The shelterwood may be removed at a later date (e.g., 5 to 10 years).



**Shelterwood**

**Selection** - Individual or groups of trees are harvested to make space for natural regeneration.

**Single tree selection**

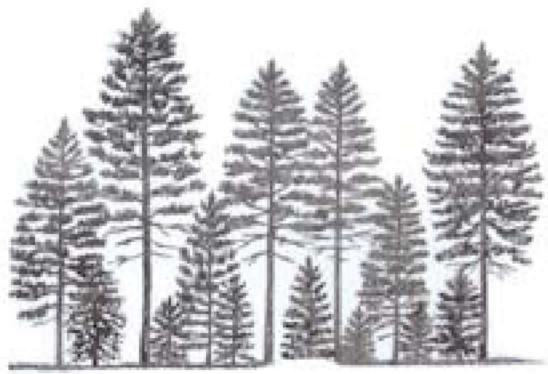


**Group tree selection**

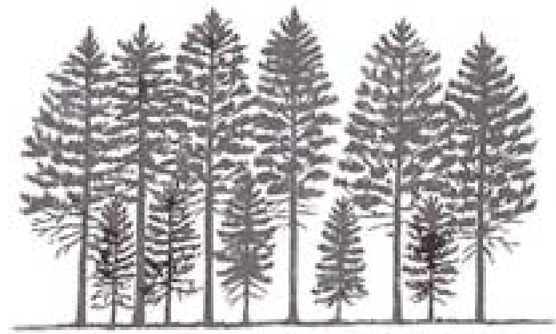
Clearcutting, seed-tree, and shelterwood systems produce forests of primarily one age class (assuming seed trees and shelterwood trees are eventually removed) and are commonly referred to as even-aged management. Selection systems produce forests of several to many age classes and are commonly referred to as uneven-aged management. However, in reality, the entire silvicultural system may be more complicated and involve a number of silvicultural treatments such as site preparation, weeding and cleaning, pre-commercial thinning, commercial thinning, pruning, etc.

Importantly, the feasibility and appropriateness of a silvicultural system depends on your objectives, existing stand conditions, the characteristics of the individual tree species involved, and your willingness and ability to make these investments. Pioneer or light-demanding species respond well to high levels of light and thus clearcutting is an effective harvest and regeneration strategy. Such species typically do not grow well in the shade. Conversely, late successional and less light-demanding species will often grow best under shelterwood or selection systems. But there are complicating forest health, cost, habitat, and aesthetic issues that hinder broad generalizations. The individual species and cover type guidelines described are intended to deal with these issues in detail.

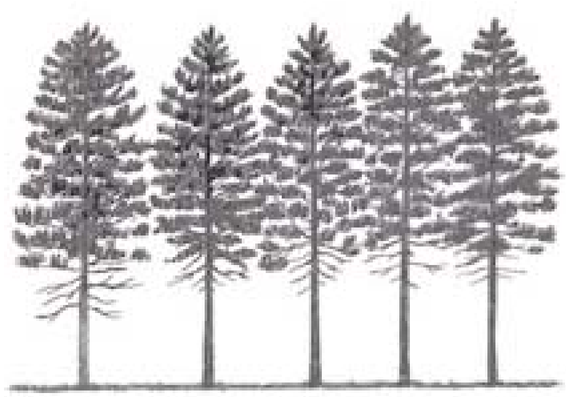
**Stand development -** In application, silvicultural treatments can lead to a change in age class structure for the new or remaining forest. Clear-cutting and shelterwood systems typically lead to an even-aged structure. Selective cutting typically leads to an uneven-age structure. Using seed trees can lead to an even-age structure for the new stand if regeneration occurs quickly; if regeneration occurs gradually, the result can be an uneven aged stand. Also, if the seed trees are left on the area for a long time period, the new stand will have two to a many age class structure. Clearly, specifying the silvicultural system for a particular stand is an important step. Even-aged management is perhaps the simplest approach in many respects, even though it constitutes a major disturbance of the site. Conversely, uneven-aged management is outwardly appealing because it leaves the site in a continuous green state. However, uneven-aged management often requires more expertise and thought in specifying choices among treatments. For either choice of age class structure, failure to consider choices carefully can lead to forest health problems and reduced productivity. In examples, we try to describe both the advantages and disadvantages of approaches.



**Uneven-aged**: a stand with trees of three or more distinct age classes, either intimately mixed or in small groups.



**Two-aged**: a stand with trees of two distinct age classes separated in age by more than plus or minus 20% of the rotation age.



**Even-aged**: a stand composed of a single age class of trees in which the range of tree ages is usually plus or minus 20% of the rotation age.

**Figure 1. Types of stand age structure (Definitions from: Helms, John A. 1998. Dictionary of Forestry.)**

### *Silviculture Treatments*

Tree and stand conditions change over time as trees grow in size and as they interact with other plants, animals, and ecological processes. Silvicultural treatments are applied to change, accelerate change, or maintain the condition of trees and stands. For example, by applying selective herbicides after planting, a desired tree species can be given a head start in growth that allows it to out compete other vegetation. By thinning a stand, the remaining trees can develop into larger stems at a rate faster than if the stand was not thinned.

Many potential silvicultural treatments might be used to change, accelerate change, or maintain tree and stand conditions. Those that are typically used to foster improved tree growing conditions and/or improved growth and yield include:

- Choice of species and site
- Site preparation
- Planting
- Spacing
- Weeding & Cleaning
- Thinning
- Pruning
- Fertilization
- Logging slash distribution

The combination of treatments used in a silvicultural system can have large impact on growth and future yields. For example, a stand managed with all of the above treatments may produce as much as four times the yields of the region wide average of such stands without treatment.

**Species and Site Selection** - The choice of tree species to plant on a site is an early and very important step in starting or regenerating a forest. Tree species can have very different requirements in terms of soil nutrient and moisture resources, and sites can vary widely in the extent or character of resource regimes. By careful matching of species and sites, the chances of achieving a healthy and productive forest are greatly improved. A useful approach for determining appropriate forest composition (including choice of commercial timber species) is to determine the native forest ecosystem, habitat type, or plant community of your site. There are several detailed regional references that provide the tools to make this determination including the Minnesota Department of Natural Resources web page on Minnesota's Native Plant Communities and the Wisconsin Forest Habitat Type Classification System (PDF, 146K).

**Site preparation -** Given a particular site, there may still be important steps available to ensure that the planted trees have the best possible start. By controlling (either removing or slowing) the growth of competing vegetation, the desired trees face less competition for site resources and can thereby establish dominance in competition for resources. Additionally, site preparation can prepare very specific microsite conditions favorable to tree growth, e.g., soil loosening, moisture, insect, and disease control, competing vegetation management, etc. These effects can be accomplished manually, mechanically, and/or with herbicides. In terms of the remaining overstory vegetation, tree species also differ widely in shade tolerance. Depending on the tree species, leaving overstory trees that provide shade can increase the chance of successful establishment by reducing heat and moisture stress. However, for shade intolerant species (typically pioneer or light demanding species), full sunlight will prove most effective. For shade intolerant species, excessive shade will decrease initial growth. Once the seedlings grow higher than neighboring competing vegetation, they are typically described as "free to grow". Competition is then managed by thinning rather than herbicides or other control techniques. Recommendations for site preparation are given for both tree species and existing site conditions. Details of these recommendations for typical sites and tree species are available in the tree specific guides sections.

The most commonly used site preparation techniques in the Lake States are:

- TTS disk trenching
- Leno scarification
- Combined mechanical/chemical application with a boom sprayer at the back of TTS

**Exposed soil after scarification. (Eli Sagor)**

**Planting -** Proper planting is crucial for tree survival and growth. If a tree is planted too deep or too high with respect to the soil surface, the seedling may be unable to access site resources effectively and will die or develop slowly with greater susceptibility to diseases and insects and thereby face increased risk of mortality or lessened tree quality. It is particularly important that the root system makes full contact with the soil and be positioned to favor normal development and growth. Poor planting can also increase susceptibility to windthrow later in life.

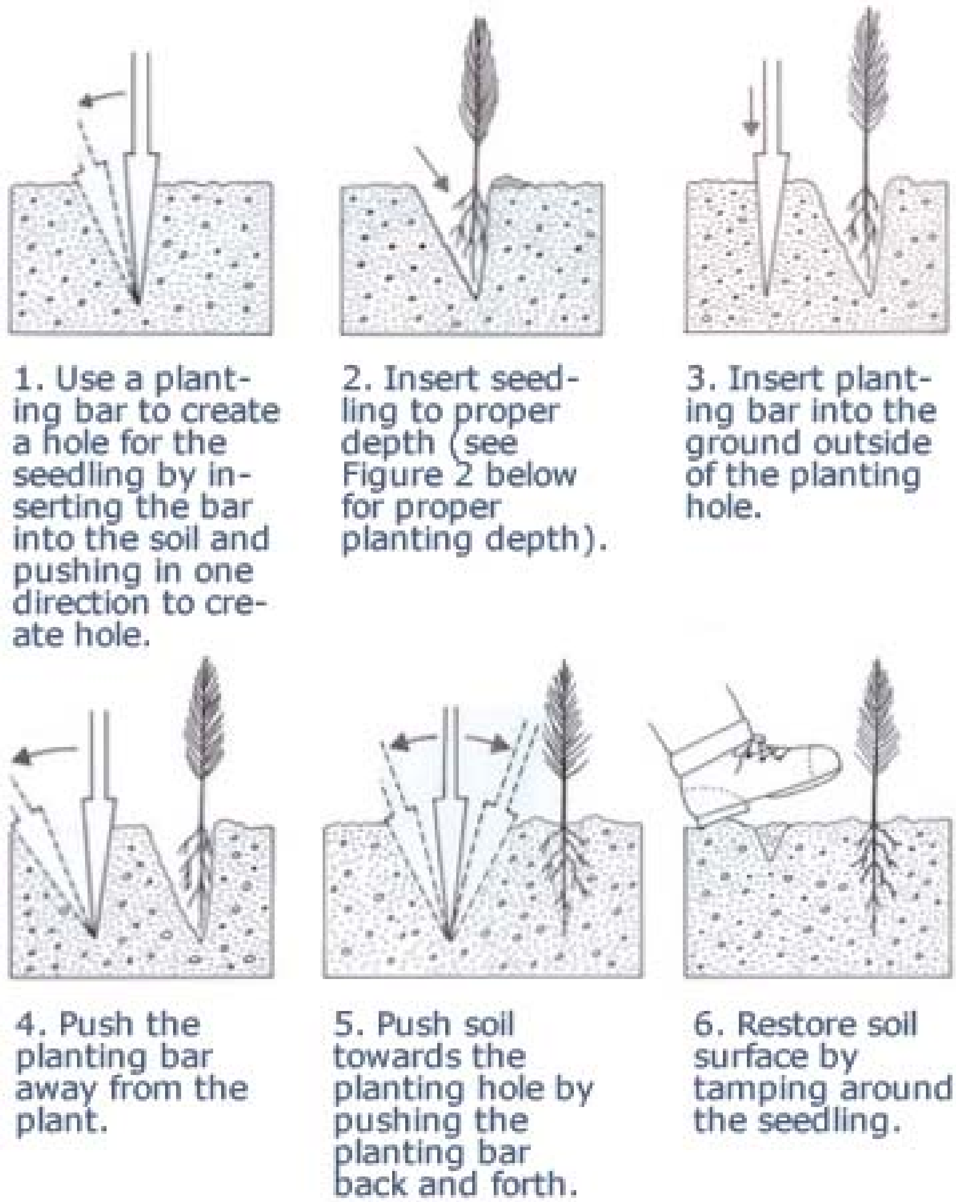



**Figure 1. How to plant a seedling.**

**Spacing -** Spacing of seedlings is an important consideration. Spacing, or planting density will vary with objectives, forest type and condition, and species. For more details on spacing, see the information about planting in the tree species specific guide sections.

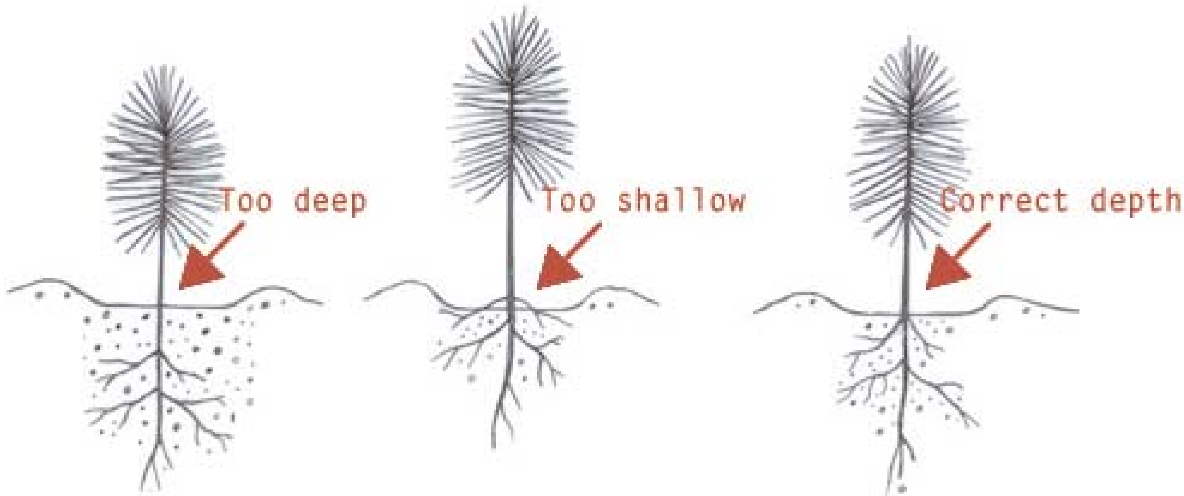



**Figure 1. How to plant a seedling.**

**Weeding and Cleaning** - Until the planted trees have grown beyond the height of competing vegetation (sometimes termed weeds), there remains a high probability of mortality. Controlling (reducing) competition can greatly reduce mortality of desired tree species. Some typical types and applications of weeding and cleaning are:

**Red pine planting. Southwest Wisconsin. (A. Ek)**

**Manual brush control (B. Palik)**

1. Mechanical weed control (removal or destruction) by hand or with machines. This is typically expensive and the least effective method as certain plants can grow back quickly.

2. Herbicide control with chemicals applied to the competing vegetation by injection of stems or ground or aerial spraying of foliage. Such chemicals can be selective in terms of differential effects on various plants. For example, certain chemicals will control broadleaved plants but not harm pines if applied in the right season and at the appropriate rate. Also see Best Management Practices for silvicultural Chemicals from USDA Forest Service.

3. Biological control can use shade of overstory trees to slow growth of competing herb and woody vegetation until the desired trees are beyond the influence of this competition.

4. Prescribed burning can be used to kill competition. However, this requires that the desired trees are fire resistant. While competing plants may resprout, retarded growth (particularly after several burns) may provide sufficient time for the desired trees to capture needed site resources.

The most commonly used weeding and cleaning techniques in the Lake States are:

1. Chemical weed control
2. Wickless applicator (brush saw with chemical dowsing)
3. Aerial application

**Pruning**

Pruning is the removal of the lower branches of a tree. You should never prune more than half of the tree height. For economic reasons, only trees which will be in the final mature forest (crop trees) should be pruned. You should prune (in either one or two steps) pole size trees up to 9', for one log of knot free sawtimber or veneer, or 17', for two logs of knot free sawtimber.

Pruning is usually done during the dormant season (fall and winter) because trees can be damaged more easily during the summer. Dead and live branches should be cut close to the stem to reduce the time of healing. It is important not to damage the branch collar to ensure optimal healing.

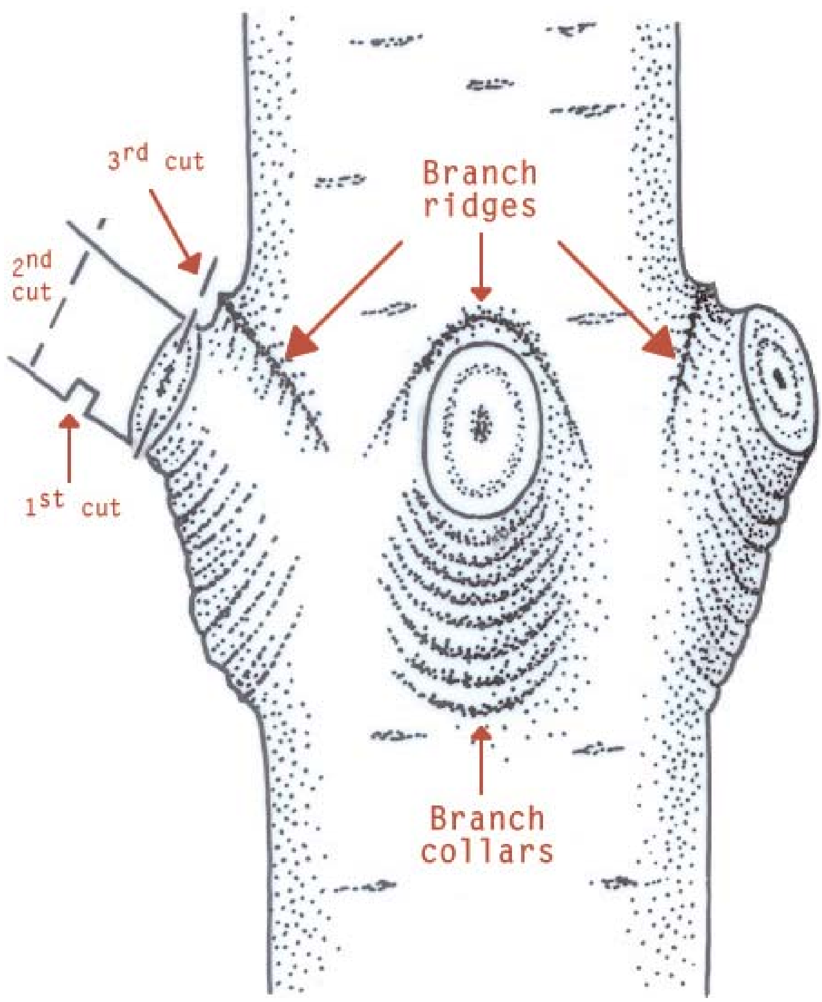



**Figure 3. The key to proper pruning is to protect the tree stem and trunk. To avoid tearing the bark and stem wood and to facilitate healing, make a small cut just (known as the wedge or notch) beyond the branch collar. Then make your second cut just beyond the notch from top to bottom. Once the branch has broken free at the notch, make a third cut parallel to and just beyond the branch collar to reduce the length of the stub.**

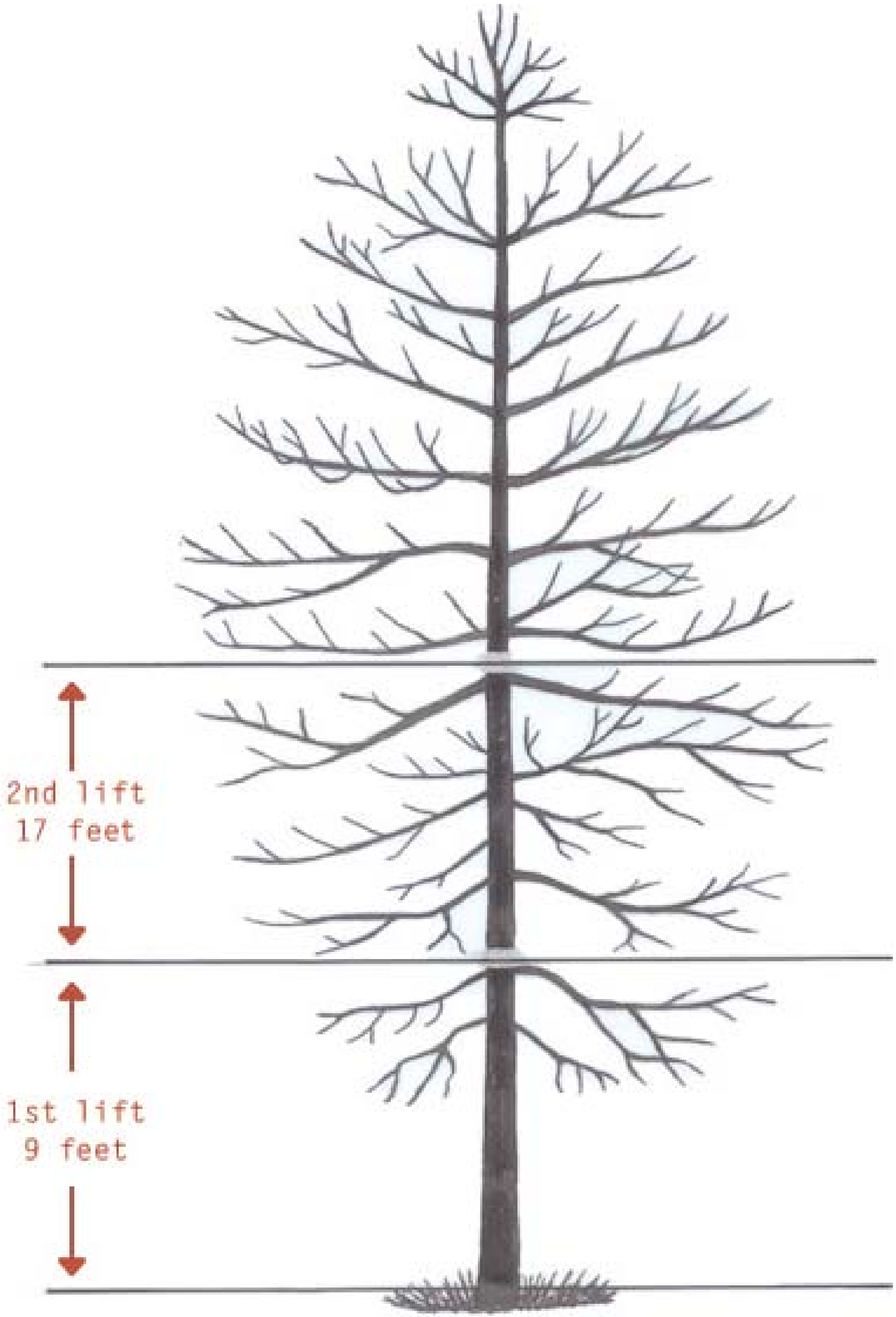



**Figure 4. Pole size trees (hardwoods 5 to 11 inches and conifers 5 to 9 inches dbh) can be pruned one or two lifts (9 to 17 feet) which results in one or two logs of knot free sawtimber or veneer.**

## Thinning

Thinning reduces mortality (or salvages it before it occurs) by reducing the number of trees per acre. The remaining trees then have more site resources to draw from and typically grow faster and healthier. By thinning at regular intervals, one can be assured that stress due to overcrowding is avoided. Thinned trees can then develop stronger root systems and be less prone to windthrow. The species composition of a stand can also be influenced by thinning, e.g., depending on which tree species are cut and which are retained. If sawlogs or veneer logs are sought, thinnings would focus on developing large and high quality stems. Thus thinning can improve growing conditions, species composition, tree quality, and the economic value of the stand. Importantly, poor thinning choices can reduce quality and economic values (e.g., highgrading or always taking the best trees and leaving the worst). However, well planned thinning can provide increases in timber values and economic returns. Specific recommendations for thinning are provided in the tree specific guide sections.

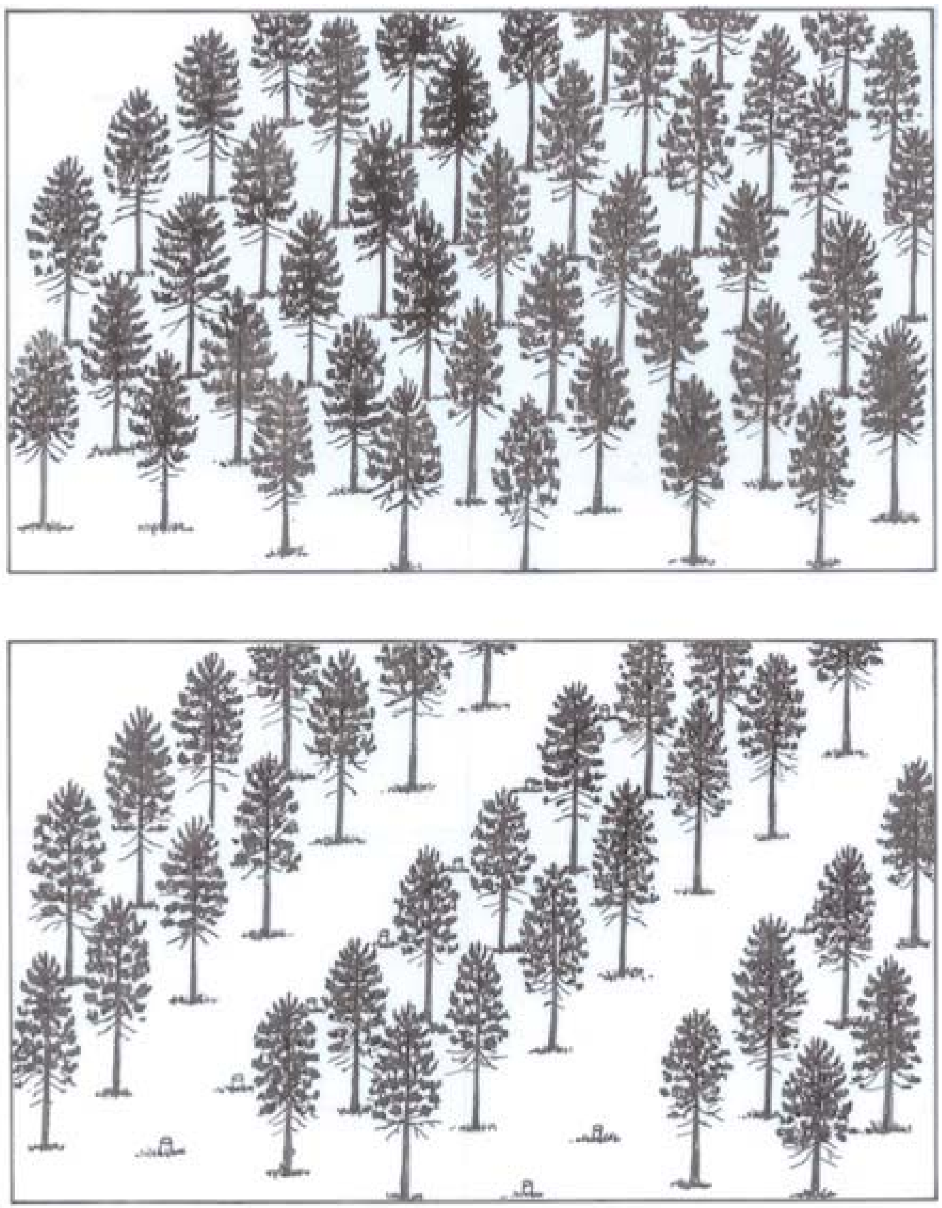


**Figure 5. Forest stand before thinning (top) and after row thinning (bottom). In this thinning example, every third row is removed.**

**Regeneration Harvesting**

As described above, thinning can remove mature trees and, consequently, is an application of harvesting in your stand. However, foresters often make a distinction between removal of trees to improve growth of remaining trees (thinning) and removal of trees to facilitate establishment of new regeneration or age cohort. The latter removal is termed a regeneration harvest. In reality, there are no clear boundaries between thinning and regeneration harvesting; thinning may allow establishment of a new cohort of trees, or regeneration harvesting may lead to improved growth of residual trees, if some are left in the stand. Rather these terms are used to communicate the primary purposes of the treatment, i.e., improved growth of residual trees or new regeneration. Regeneration harvests can be applied in many different ways which result in distinctly different stand age structures. Recall that silvicultural systems are often named for these age structures, regeneration and harvesting approaches (clearcut, seedtree, shelterwood, selection). Details on regeneration harvesting considerations are provided in species specific guides.

## *Harvesting systems*

The process of timber harvesting is comprised of five basic tasks:

1. Timber acquisition (moving to the tree).
2. Felling and preparing the tree for extraction (delimbing, topping, and segmenting).
3. Extracting the tree to a central location or landing (skidding or forwarding).
4. Loading the tree for transport to the mill.
5. Transporting the tree to a mill.

The processing of the tree into individual products (e.g., veneer logs, sawlogs, pulpwood) may occur at either the stump or at the landing. A variety of equipment options can be used to accomplish each task (Tables 1 and Table 2 below).

Harvesting systems are named based on the form in which the wood arrives at the landing. The three general types of harvesting systems include shortwood, tree-length, and full-tree. We will focus our discussion on the tasks of moving to the tree, felling the tree, processing it at the stump, and transporting the tree to the landing.

There are a variety of equipment options that can be used with each harvesting system. While a given harvest system can be used to accomplish any silvicultural objective (Table 3 below), there are distinct advantages and disadvantages for each that need to be considered (Table 4 below). While a shortwood system is suited to all types of management, a full-tree system is better suited to a production requirement because equipment frequently tends to be larger and to operate faster than for the other systems.

**Harvesting systems**

**Shortwood** (also known as cut-to-length): Trees are felled, delimbed, and bucked to individual product lengths directly in the stump area and then transported to the landing or roadside. Primary transportation is usually by a forwarder, although cable skidders are sometimes used.

**Tree-length**: Trees are felled, delimbed, and topped directly in the stump area and then transported to the landing. Transportation from the stump to the landing is usually by a skidder (cable or grapple). At the landing, the tree length sections are processed into individual products or hauled as is to a central processing yard or mill.

**Full-tree**: Trees are felled and transported to the landing with the branches and top still intact. Transport to the landing is usually by a skidder (cable or grapple). At the landing, the full trees are processed into individual products or hauled as full trees to a central processing yard or mill.

**Light-on-the-land operations**

Light-on-the-land (LOL) is an approach to timber harvesting that uses techniques and equipment designed to minimize site and stand impacts. To be successful, business owners and on-the-ground operators need to understand and apply light-on-the-land approaches too. Operators who have and apply a light-on-the-land ethic are critical. As all sites and conditions do not require the same treatment, and there may be many ways to accomplish a silvicultural objective through logging, it is important to recognize where LOL approaches are needed. The need for LOL increases as:

- the silvicultural prescription includes more residual trees because of the need to protect those remaining trees from scarring and rot damage and because it takes more time and care to work around residual trees, and;
- site conditions warrant (e.g., soils that are wet, non-frozen, or have more loam, silt, or clay; steep topography).

**Light-on-the-land techniques**

Individual state best management practices or forest management guidebooks often include a wealth of LOL techniques to protect water quality and site productivity such as:

- Combine and integrate management activities to reduce trafficking on the site
- Avoid unnecessary stand re-entry
- Operate on snow or when soils are frozen or dry
- Avoid operating during periods when insect infestations are possible
- Avoid rutting within the site and hydrologic impacts from roads and skid trails
- Divert water from roads, skid trails, and landings
- Revegetate exposed areas
- Infrastructure (roads, skid trails, and landings)
  - Minimize within the harvest site
  - Share between harvest sites
  - Plan during stand establishment
  - Use designated trails
- Avoid full-tree harvesting on nutrient-sensitive sites
- Retain or redistribute slash on nutrient-sensitive sites
- Operate machinery along the contours, rather than up and down slopes
- Store lubricants and fuels in appropriate (e.g., approved, labeled) containers that are located away from water
- Incorporate and administer appropriate regulations in the timber sale contract

Techniques that do not often appear in guidebooks include:

- When thinning a stand, mark it so that there is enough room for equipment to operate
- Final cuts in shelterwood, seed tree, or other situations where natural regeneration has established should be planned for winter when snow cover protects seedlings and the soil is frozen
- Swing trees out of sensitive areas using felling machinery. Use the full reach of a mechanical boom whenever possible.
- Minimize turning and curves when planning skidding trails during thinning operations. The best skid trail route is generally the straightest possible, over the most level terrain.
- Locate skid trails to accommodate future as well as current harvests. Use designated skid trails to reduce trail density and to control the path of skidders and forwarders.

- Select open areas along skid trails where skidders and forwarders can turn around and then back up to a load.
- Consider the dimensions of logging equipment when planning trails and roads. Where possible, match equipment size to the size of the timber to be harvested. Because they are shorter and can maneuver more easily through residual trees, horses and forwarders may be a better choice than skidders.
- For thinning operations,
    - Consider use of a tree-length or shortwood harvesting system as the tree size (i.e., length or the material and elimination of the branches and top material) is reduced as compared to the full-tree system.
    - Use directional felling techniques to align stems at a thirty to forty-five degree angle to the trail to limit trafficking
    - Cut stumps as low as possible on skid trails to reduce load shifting.
    - Designate bumper/rub/turn trees at curves and turns in the skid trail to protect the residual trees from scarring.
- If ground strength permits, maximize payloads to reduce the number of required trips.
- Communicate the harvest plans to the buyer and on-the-ground operator(s) through an on-site walkover conducted prior to commencing any harvesting activities.

**Light-on-the-land equipment**

In addition to the techniques identified above, existing equipment may be modified or other equipment used to address specific concerns. Some of the possible options are noted below:

- Equipment modifications
    - Swing-to-tree vs. tree-to-tree felling equipment

**Swing-to Tree Harvester**

**Tree-to-tree feller buncher**

- Cable vs. grapple skidding

**Cable skidder**

**Grapple skidder**

- Aerial yarding systems from stump to landing

- Spread equipment weight over a wider area to reduce the pounds/square inch of weight (low ground pressure options)

**High flotation tires**

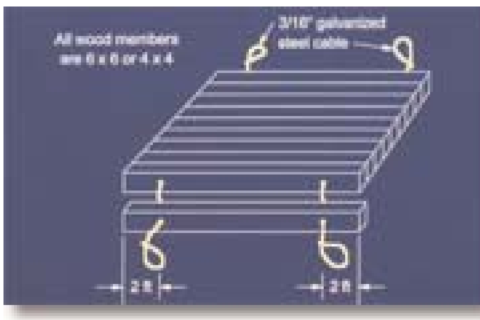
**Dual tires**

**Wheel tracks**

**Tracked machinery**

- ❍ Reduce machine weight/small-scale equipment

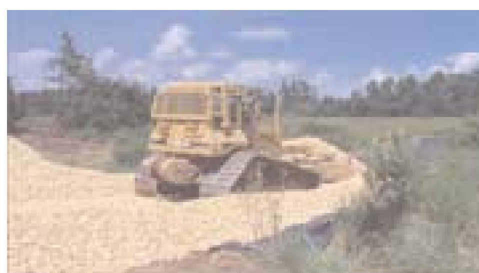
■ Apply temporary crossing structures over areas with weak soils




**Wood mats**

**Wood pallets**

**Drive on slash mats or corduroy**



**Wood aggregate**

**HDPE plastic**

Tree-to-tree feller-bunchers traverse more of the area and lead to more scarification than excavator-type feller-bunchers or chain saw felling

As compared to tree-length skidding, full-tree skidding increases scarification because limbs act as a rake. If organic matter is thick or understory vegetation is dense the opposite may be true.

Skidding increases the amount of scarification over forwarding since limbs or tops are allowed to drag.

Felling machines with the ability to remove trees from both the front and side of the machine allow you to thin within leave rows. Select machinery with zero or minimal tail swing so that the machine's width is no wider than the tires or tracks.

Availability of a small felling machine with a narrow forwarder or skidding allows you to specify a narrower thinning corridor. The tradeoff may be that you remove more rows because of the limited reach of the machinery.

Mechanical fellers (e.g., cut-to-length feller processor) with a telescoping boom better protect the overhead components of the stand than does a knuckleboom.

**Table 1. Basic harvesting components, associated activities, and options for accomplishing each component.**

| Component | Possible activities | Options |
|---|---|---|
| Timber acquisition | Move to tree prior to felling | Walk<br><br>Machine (rubber or tracked)<br>Drive-to-tree<br>Swing-to-tree |
| Felling | Fell, limb, top, buck into individual products | Chain saw<br><br>Mechanical<br>Bunching operation<br>No bunching |
| Primary transportation | Move felled tree(s) to central landing | Animal<br>Horse<br>Skidder (rubber or tracked)<br>Cable<br>Grapple<br>Clambunk<br>Forwarder<br>Cable yarding |
| Processing | Delimb, buck/slash into individual products, debark, chip, or no processing | Delimber<br>Chain saw bucking<br>Mechanical slasher<br>Debarker<br>Chipper |

**Table 1 Cont'd. Basic harvesting components, associated activities, and options for accomplishing each component.**

| Component | Possible activities | Options |
|---|---|---|
| Loading | Load products onto or into over-the-road vehicle | Loader<br>Forwarder |
| Secondary transport | Over-the-road vehicle transports products to mill | Trailer<br>Chip van |

**Table 2. Characteristics of timber harvesting systems in Minnesota.**

| Characteristic | Shortwood | Tree-length | Full-tree |
|---|---|---|---|
| Felling equipment | Chain saw<br>Harvester | Chain saw<br>Feller-buncher<br>Harvester | Feller-buncher |
| Off-road transport equipment | Forwarder<br>Cable skidder (limited use) | Cable skidder<br>Grapple skidder<br>Cable yarder<br>Horses | |
| Delimbing and topping location | Stump area | Stump area<br>Cut-over (concentrated within cut-over) | Roadside<br>Not delimbed |
| Bucking location | Stump area | Roadside<br>Off-site<br>Not bucked | |
| Slash distribution | Evenly spread<br>Windrows | Evenly spread<br>Small piles | Roadside piles<br>No slash left |
| Roadside landing requirements and impact | Small | Large | Largest |
| Maximum effective off-road transport distance | 2000 ft. | Cable & grapple skidders - 1000 ft. | |
| Access road requirement[1] | 27 ft./acre | Cable & grapple skidders - 40 ft./acre | |
| Area with vehicular traffic | Low | Cable & grapple skidders - heavy | |

| Characteristic | Shortwood | Tree-length | Full-tree |
|---|---|---|---|
| Ground disturbance - dry | Low | Moderate | Heavy |
| Ground disturbance - frozen | Minimal | Low | Low |
| Ground disturbance - wet | Moderate | Heavy | Heavy |
| Protection of residual trees and regeneration | Good | Moderate | Poor |

Source: Jaako Pöyry Consulting, Inc. 1992. Harvesting systems: A background paper for a Generic Environmental Impact Statement on timber harvesting and forest management in Minnesota. Jaako Pöyry Consulting, Inc., Tarrytown, NY. 50 p.

[1] Length of road required, on average, to access an area for logging.

**Table 3. Applicability of timber harvesting systems to silvicultural systems and operations.**

| Operation | Shortwood | Tree-length | Full-tree |
|---|---|---|---|
| **EVEN-AGE** | | | |
| clearcutting<br>clearcutting w/ standing snags & live trees<br>patch cutting<br>alternate strip cutting<br>progressive strip cutting | Good | | |
| shelterwood cutting | Good | Moderate | Poor |
| seed tree cutting | Good | Good | Moderate |

<table>
<tr><th>Operation</th><th>Shortwood</th><th>Tree-length</th><th>Full-tree</th></tr>
<tr><td colspan="4">UNEVEN-AGE</td></tr>
<tr><td>individual tree selective cutting</td><td>Good</td><td>Poor</td><td>Poor</td></tr>
<tr><td>group selective cutting</td><td>Good</td><td>Moderate</td><td>Poor</td></tr>
<tr><td colspan="4">OTHER</td></tr>
<tr><td>selective thinning</td><td rowspan="3">Good</td><td>Poor</td><td rowspan="3">Poor</td></tr>
<tr><td>row thinning</td><td>Moderate</td></tr>
<tr><td>overstory removal (shelterwood & seed tree)</td><td>Moderate</td></tr>
</table>

**Table 3 Cont'd. Applicability of timber harvesting systems to silvicultural systems and operations.** Source: Jaako Pöyry Consulting, Inc. 1992. Harvesting systems: A background paper for a Generic Environmental Impact Statement on timber harvesting and forest management in Minnesota. Jaako Pöyry Consulting, Inc., Tarrytown, NY. 50 p.

**Table 4. Advantages and disadvantages for the three harvesting systems.**

| Harvesting system | Advantages | Disadvantages |
|---|---|---|
| **SHORTWOOD** | Low initial investment and operating costs (sometimes)<br><br>Less adverse site impacts<br><br>Stems remain clean and are less prone to breakage<br><br>Residues remain at the stump<br><br>Branches and slash may be left on skid trails, protecting soil and roots<br><br>Less support equipment needed<br><br>Smaller landings needed<br><br>Skid trails may be meandering<br><br>Narrower skid trails needed | High initial investment and operating costs (sometimes)<br><br>Lower production<br><br>May be labor intensive (skilled labor, workers' compensation)<br><br>Can't put on a heavy load on steeper slopes<br><br>Slash mat may be inadequate to fully support some equipment |

| Harvesting system | Advantages | Disadvantages |
|---|---|---|
| **TREE-LENGTH** | Branches remain at the stump<br><br>In-stand residue helps to protect the soil from machine traffic<br><br>Roadside slash is greatly reduced<br><br>Landings are somewhat smaller<br><br>Skid trails don't have to be as wide<br><br>Bumper trees for load compression are less critical | Wood tends to be dirty<br><br>Soil damage in skid trails may be greater if branches are not left on the trails<br><br>Damage to residual trees and seedlings may be greater/Bumper trees are needed |
| **FULL-TREE** | Maximizes volume recovery/unit area<br><br>Highly mechanized with high productivity<br><br>Less labor/unit volume<br><br>Concentrates many operations at a central point, permitting bulk operations. This is a particular advantage when trees are small<br><br>Softwood limbs reduce soil disturbance and damage to residual stand<br><br>Cutover area is left clear of residue, minimizing site preparation and planting costs<br><br>Generally the lowest possible harvest cost/unit | High initial investment and operating cost<br><br>Requires a lot of support equipment/larger landing space is required<br><br>Moves are more expensive<br><br>More timber required in short- and long-run<br><br>Machines may be heavy, causing root damage, soil compaction, and possible rutting<br><br>High flotation tires may be needed, thus increasing cost and minimum trail width<br><br>Limbs increase load width and may cause damage to residuals<br><br>Loss of high value may occur<br><br>May result in more slash at the landing<br><br>Residues are not left at the stump<br><br>More seed cones and nutrients are removed from the forest |

### *Managing for Ecological Objectives*

Managing for ecological objectives often involves maintaining or enhancing ecological complexity in a stand, as determined by structural and compositional characteristics. It is a fact that traditional silvicultural approaches, especially those that are aimed primarily at management for timber, simplify the structure and composition of forest stands relative to conditions occurring in unmanaged (and naturally disturbed) stands. If your objectives include management for native species diversity, non-game wildlife habitat, and more aesthetically diverse conditions, than you should consider managing stands to enhance ecological complexity.

Ecologically complex stands are typically composed of more than one tree species, often including species that have little or no commercial value. Complex stands often include more than one age class, or at least some older individuals within the stand. Complex stands tend to have a wider range of tree sizes, including some (or sometimes many) very large individuals. Ecologically complex stands may contain abundant and sometimes diverse understory and groundlayer plant communities. Complex stands tend to have abundant numbers of standing snags and dead trees on the ground, as well as trees of limited commercial but high ecological value, such as cavity trees and wolf trees (Figure 1).

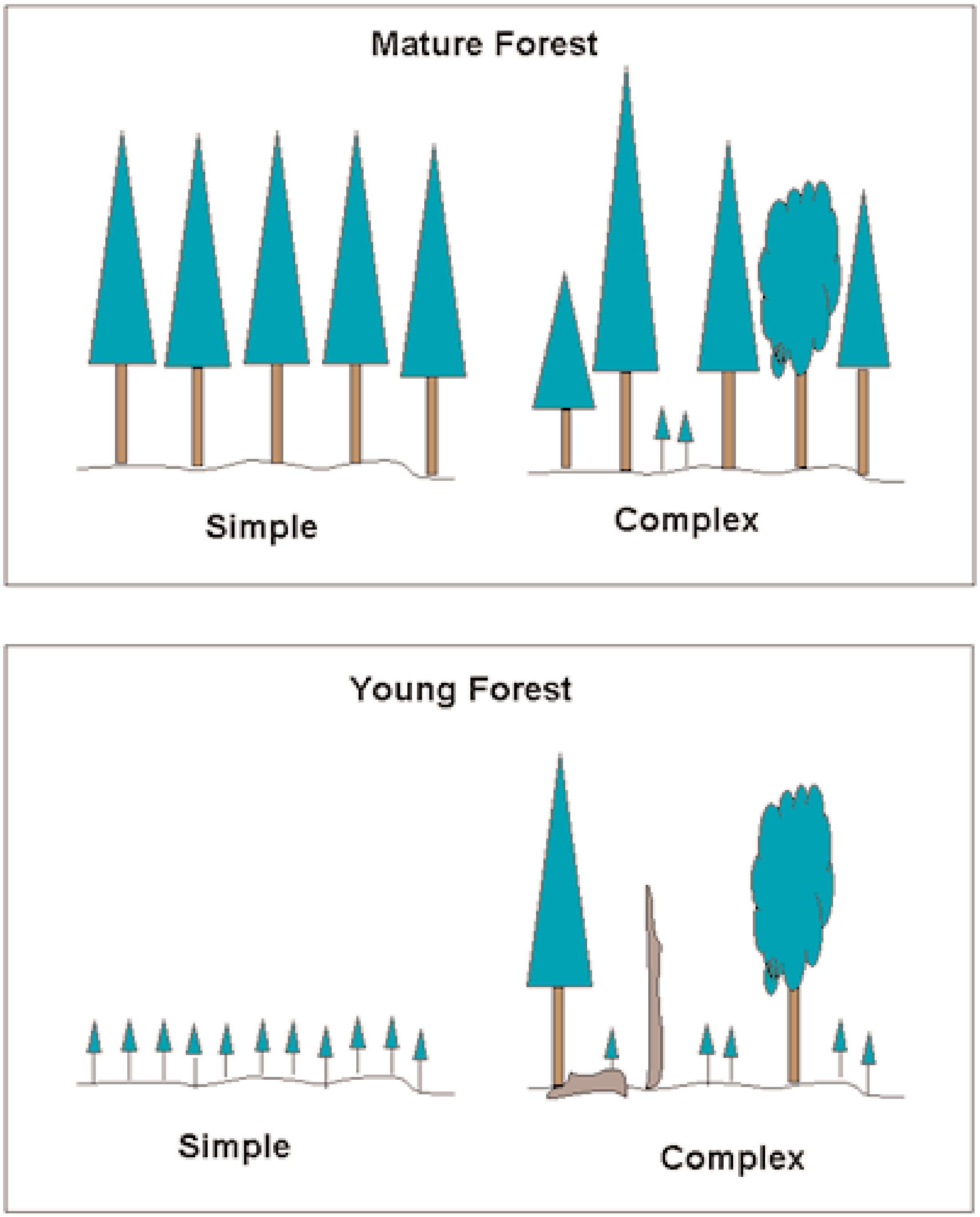



**Figure 1. Stylized representation of structurally simple versus structurally complex stands for both mature (top) and young (bottom) stand conditions.**

Ecological complexity also is expressed as spatial variation or heterogeneity in the above characteristics. In other words, complex stands vary in structure and composition from one spot to another, compared to simplified stands that are often uniform throughout in their structure and composition. The sustainability of native species populations (one aspect of biological diversity) is often dependent on the availability of structures and the heterogeneity that exists in complex forest stands.

This is not to say that all stands should be equally (or highly) complex, indeed a range of variation should exist in the broader landscape. The level of ecological complexity you might desire will depend on the dominant species in your forest and your objectives (for example, a mixture of objectives including timber management or primarily songbird watching). Not all forest types are equally complex naturally. For instance, jack pine forests are naturally less complex in structure and composition than are northern hardwood forests. However, virtually all forests, including jack pine, that are managed principally for timber are less complex when compared to unmanaged, naturally occurring stands of the same type. Another point to remember is that stand complexity is not simply a feature of mature and old-growth stands. Even young stands regenerating after stand-replacing natural disturbance display significant complexity in terms of residual live trees that occurred singly or in patches, as well as abundant snags and logs on the ground, and patches of undisturbed understory vegetation (Figure 1).

**Emulation of Natural Disturbance and Stand Development**

A general framework for adding ecological complexity to forest stands is to implement management activities, particularly regeneration harvesting and thinning, in ways that emulate the outcomes of natural canopy disturbances (harvesting) and natural stand development processes (thinning). You can accomplish regeneration harvests in ways that sustain or enhance the number of tree species in the stand, as well as the size and age range of trees, the number of snags and downed logs, and the abundance and types of understory plant species. Similarly, you can implement commercial thinning, and other intermediate stand treatments, in ways that increase spatial heterogeneity in structure and composition.

An essential first step in applying principles from natural disturbance regimes and stand development to ecological forestry is to understand that creating and perpetuating appropriate structural, functional, and compositional attributes in stands is often the primary management objective. Adopting a mind-set of forest continuity rather than forest termination is helpful in opening yourself to the possibilities inherent in ecological forestry. You must put aside the notion that all forest stands must be terminated and new ones regenerated at some point in the future! Ecologist have learned that at least some structural elements of the stand (e.g., large live trees, snags, downed trees) are continuously maintained even under stand-replacement disturbance regimes and that such stands can often be managed with sufficient levels of retention so as to maintain at least some level of continuous forest influence over the site. Of course, where tree- and gap-based disturbance regimes are characteristic of the forest type or site, natural stands are rarely, if ever, terminated. In a very real sense, natural situations in which forest stands are completely terminated and replaced by a new stand are rare rather than common , however common we have made even-aged stands in production-oriented landscapes.

**Principles of Ecological Forestry**

Forest management focused heavily on enhancing ecological complexity is an evolving area of interest. It can be a major objective or be incorporated into management for objectives such as income, wildlife habitat, or recreation. It involves consideration of three basic principles:

- Incorporation of biological legacies (features of pre-disturbance forests) into harvesting prescriptions
- Incorporation of natural stand development processes into intermediate treatments
- Allowing appropriate recovery periods between regeneration harvests

*Principle 1: Incorporation of biological legacies into harvesting prescriptions*

Biological legacies are the organisms, structures, and biologically-created patterns that persist from the pre-disturbance forest and influence development in the post-disturbance stand. These legacies include those described in Table 1.

**Table 1. Categories of biological legacies with some examples of types.**

| **Legacy Category** | **Examples** |
|---|---|
| Organisms | Sexually mature and intact live trees<br><br>Tree reproduction (seedling and sapling banks)<br><br>Vegetatively reproducing parts (e.g., roots)<br><br>Seed banks<br><br>Shrub, herb, bryophyte species<br><br>Mature and immature animals and microbes |
| Organic matter | Fine litter<br><br>Particulate material |
| Organically-derived structures | Standing dead trees<br><br>Downed trees and other coarse woody debris<br><br>Root wads and pits from uprooted trees |
| Organically-derived patterns | Soil chemical, physical, microbial properties<br><br>Forest understory composition and distribution |

Biological legacies persist even through the most intense stand-replacement disturbances; they play critical roles as habitat and modifiers of the physical environment; and they are difficult or impossible to re-create in managed stands, hence the interest in carrying them over from the pre-disturbance stand.

**Even-aged Management -** One can easily modify even-aged regeneration harvests to incorporate biological legacies by retaining some large (healthy) trees of the dominant species as well as other species, by not cutting decadent trees and snags, and by protecting or creating some dead and downed trees. Consider including a range of sizes of retained trees, snags, and down trees (coarse wood debris), including large and very large trees. Also, you might give special consideration to retaining actual or potential habitat trees, including cavity trees, mast trees, nest trees, etc. Finally, try to retain and protect natural regeneration of desired species when it occurs.

The number or amount of structures (live trees, snags, logs, etc.) you might retain is dependent on management objectives and desired future conditions. For instance, retention of a low stand density or basal area of residual trees (e.g., 10-20 ft 2 /ac), followed by regeneration, will result in a largely single age stand containing scattered older trees. In contrast, retention of 30-50 ft 2 /ac of residual basal area will result in stands better described as two-aged. Keep in mind that there may be growth reductions when regenerating intolerant species under even modest levels of a residual overstory. However, maximizing regeneration growth throughout the stand is not of primary concern when managing for ecological complexity. Moreover, the continued growth of the residual trees may help to compensate for growth losses of regeneration.

You also should consider the spatial pattern of biological legacies within your harvest unit. Some ecological objectives are best sustained by dispersing retained structures (live trees, snags, coarse woody debris, etc.) over the harvest unit while other objectives are best served by aggregating structures (Figure 2). Within a single harvest unit, the retention pattern may vary from dispersed to aggregate by alternating between patch and dispersed cutting across the stand. In this way, spatial variation in stand structure is assured. Moreover, retaining some large patches of live trees is a straightforward way to insure protection of undisturbed understory plant communities and forest floor environments.

**Two-Aged Management -** With minor adaptations, two-aged systems provide excellent opportunities to incorporate biological legacies in management. Many of the same consideration outlined for even-aged management are also applicable to two-aged systems. As with even-aged systems, you might retain overstory trees (and other legacies) in spatial patterns that range from dispersed to aggregated within the same harvest unit.

Two-aged stands, that leave significant numbers of overstory trees in aggregates, or clumps, provide good opportunities to protect understory plant communities and forest floor environments since there can be places in the stand where harvesting and traffic is easily excluded.

**Uneven-aged Management -** Retention of biological legacies is also relevant to silvicultural prescriptions for uneven-aged management, i.e., single-tree and small group selection. You can easily modify selection prescriptions to incorporate biological legacies. Marking guidelines can explicitly incorporate objectives of maintaining old and large trees and their derivatives (large snags and downed boles) as part of the stand. If group selection is used, you can retain snags and downed boles, and occasionally live trees, in the gaps. The size and shape of openings used with group selection can also be chosen to match the sizes and shapes of gaps created by natural disturbances, which typically include a greater number of small openings than large ones .

*Principle 2: Incorporation of natural stand development processes into intermediate treatments*

This principle involves activities that are comparable to intermediate stand-level treatments in traditional silviculture, such as thinning and pruning, and may include such practices. However, the objective is to create structural and compositional diversity and heterogeneity throughout the stand, rather than to concentrate growth on selected trees and create spatially uniform stands, which is the case with usual stand tending treatments.

Foresters generally model intermediate stand-level treatments such as thinning and pruning on natural stand development processes, including competitive tree mortality and tree decline with age. In application, traditional thinning and pruning regimes create spatially uniform stands. To increase ecological complexity in established stands, consider modifying intermediate treatments to include variable density thinning and ecological under burning (in appropriate forest types), as well as non-traditional activities such as decadence creation and introduction of compositional diversity.

**Variable density thinning -** Thinning is typically distributed equally across a stand specifically to create a uniform distribution of equally sized crop trees, all having equal access to light, water, and soil nutrients. In contrast, most stands where natural thinning is occurring display greater spatial variation in tree densities, growth rates, and tree sizes. Moreover, competitive thinning is augmented by small-scale canopy disturbances from wind, lightning, insects, or fire that can occur at virtually anytime during stand development.

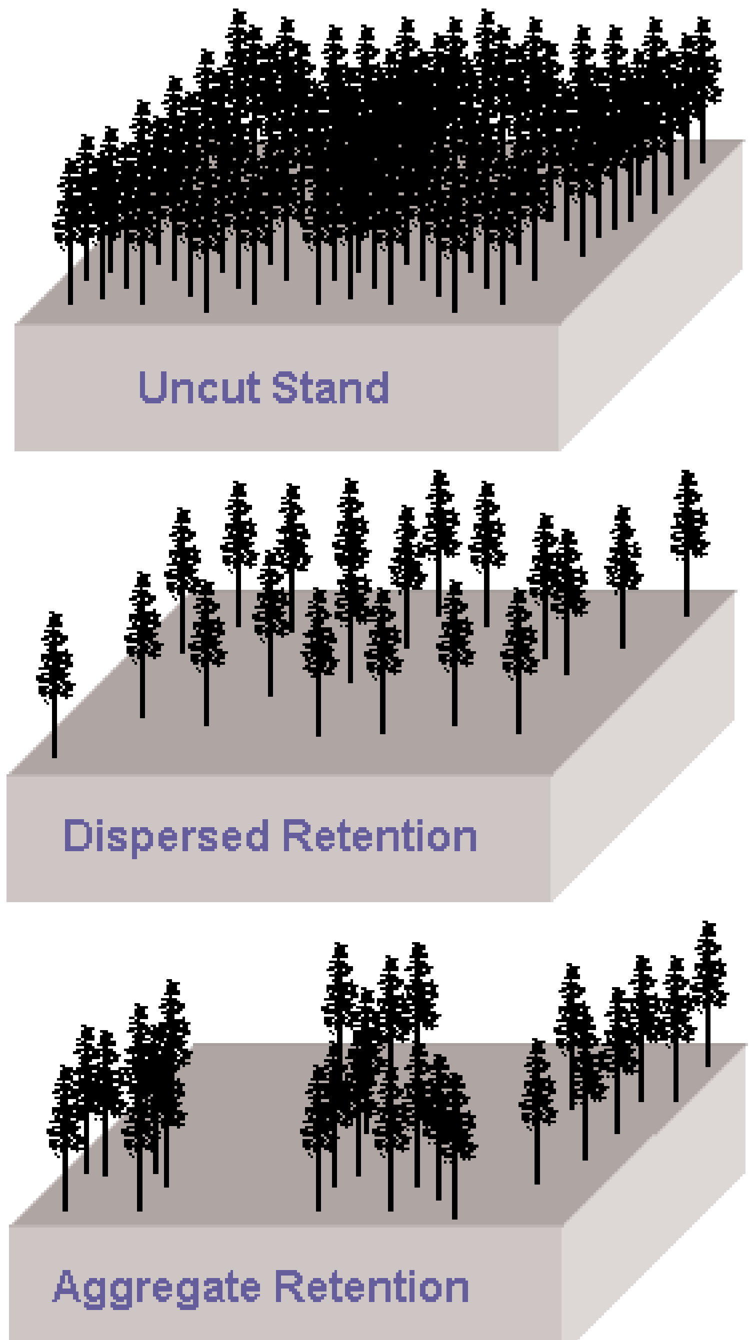



**Figure 2. Stylized representation of overstory retention harvesting. (top) unharvested stand; (middle) dispersed retention; (bottom) aggregate retention.**

Variable density thinning is an approach that emulates the natural variation that results from both competitive mortality and small-scale canopy disturbance. With this approach, your thinning pattern will include unthinned areas and heavily thinned patches (i.e. gaps), along with variable levels of thinning and residual density between these endpoints (Figure 3). The result is greater spatial variability in stand densities, thus providing for greater complexity and heterogeneity in structural conditions across the stand.

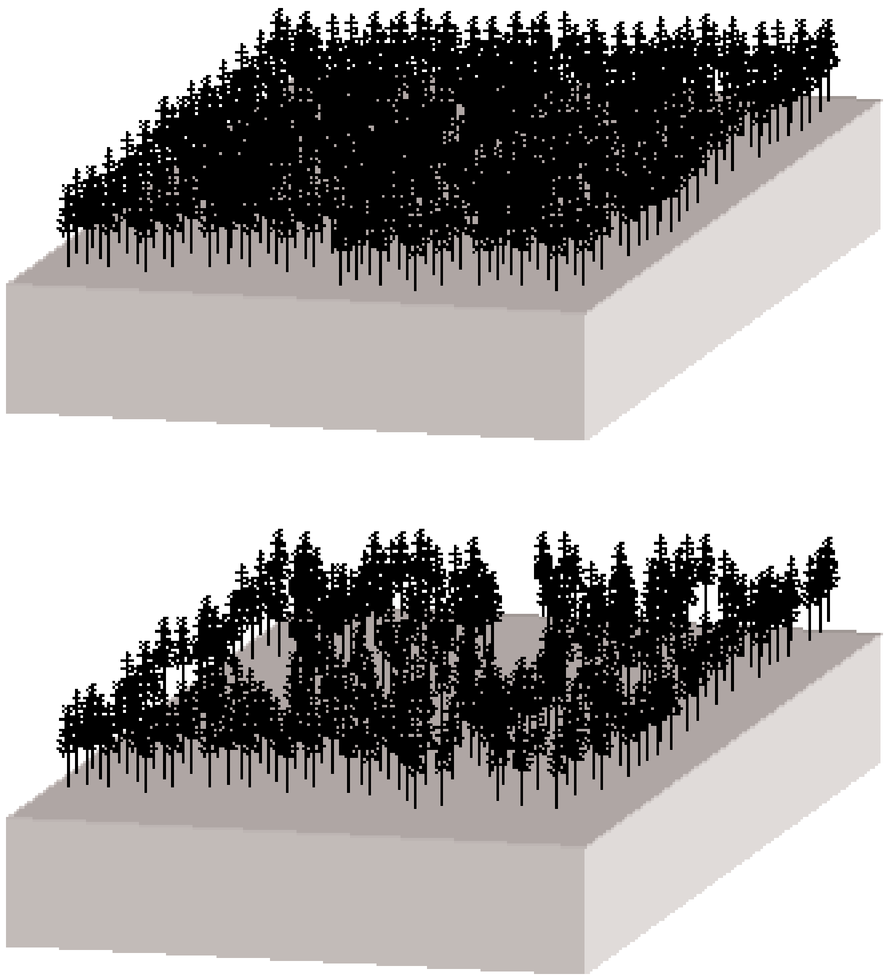


**Figure 3. Stylized representation of variable density thinning. (top) unthinned stand; (bottom) variable thinned stand..**

**Ecological under burning -** Periodic surface fires were a natural occurrence in several regional forest types, including red pine, mixed-pine, and oak. Periodic use of prescribed surface fire can help maintain (or restore) understory conditions that are reflective of conditions occurring prior to regional fire suppression. To promote ecological complexity, consider prescribed burning yet allowing the fires to burn heterogeneously across the stand, that is, make no special effort to insure that the entire stand burns evenly. Moreover, periodic surface fires can be an effective means of inducing decadence creation (see below), if scattered trees are killed by the fire. Take care to avoid inducing excessive injury or mortality, as might occur if thick duff layers surround most trees or if the fire occurs during excessively dry.

**Decadence creation -** Consider deliberate felling of live trees to increase the abundance and types of dead trees (coarse wood debris) on the ground. Also, consider girdling (or killing in some other way) living trees to create snags. A range of tree sizes should be considered, including large diameter stems. Use of blasting cord to damage the crowns of live trees is another approach for creating snags. This method creates conditions and rates of decline that are similar to that occurring after a fatal lightning strike.

**Red pine snag created using blasting cord to remove the live crown. Chippewa National Forest, Itasca County, MN (H. Tjader)**

**Introduction and conservation of compositional diversity -** When applying variable density thinning with large gaps, you may promote the establishment of additional mid- and intolerant tree, shrub, and herbaceous species in the stand. Moreover, during the course of stand development, shade tolerant species may become established in the canopy. Encourage the establishment of these species for their contributions to ecological complexity and native plant diversity. Moreover, when thinning, consider leaving non-commercial tree species in the stand, i.e., retaining these species for their contributions to ecological complexity, biological diversity, and wildlife habitat and food. Finally, consider underplanting tolerant species, e.g., eastern white pine under red pine, where seed sources or advance regeneration is lacking.

*Principle 3: Allowing appropriate recovery periods between regeneration harvests*

Recovery periods between regeneration harvests are needed for development of significant structural and compositional complexity in forest stands after disturbance. Stands managed primarily for timber are typically harvested before significant levels and types of complexity have developed (Figure 4). Most commercially managed stands lack trees of very large diameter, significant amounts of large dead wood, and trees with unique structures (cavities, large limbs, heartwood). Moreover, they may be compositionally limited, particularly in the canopy, because not enough time has passed for tolerant species to be recruited from the understory into gaps opened by natural thinning and disturbance. This problem is compounded if the stand was deliberately or inadvertently simplified during establishment, e.g., no legacies retained.

In general, stands (or individual trees within them) are harvested based on size and economic considerations. In general, economic rotation ages, typically 50-90 years, are shorter than those required to develop complex stand structures. If the primary management objective is development of ecological complexity, then management based on economic rotation ages may be inappropriate. Rather, the primary determinant of intermediate harvest or rotation age in such cases would be the development of desired or acceptable levels of structural complexity, compositional diversity, and within-stand heterogeneity.

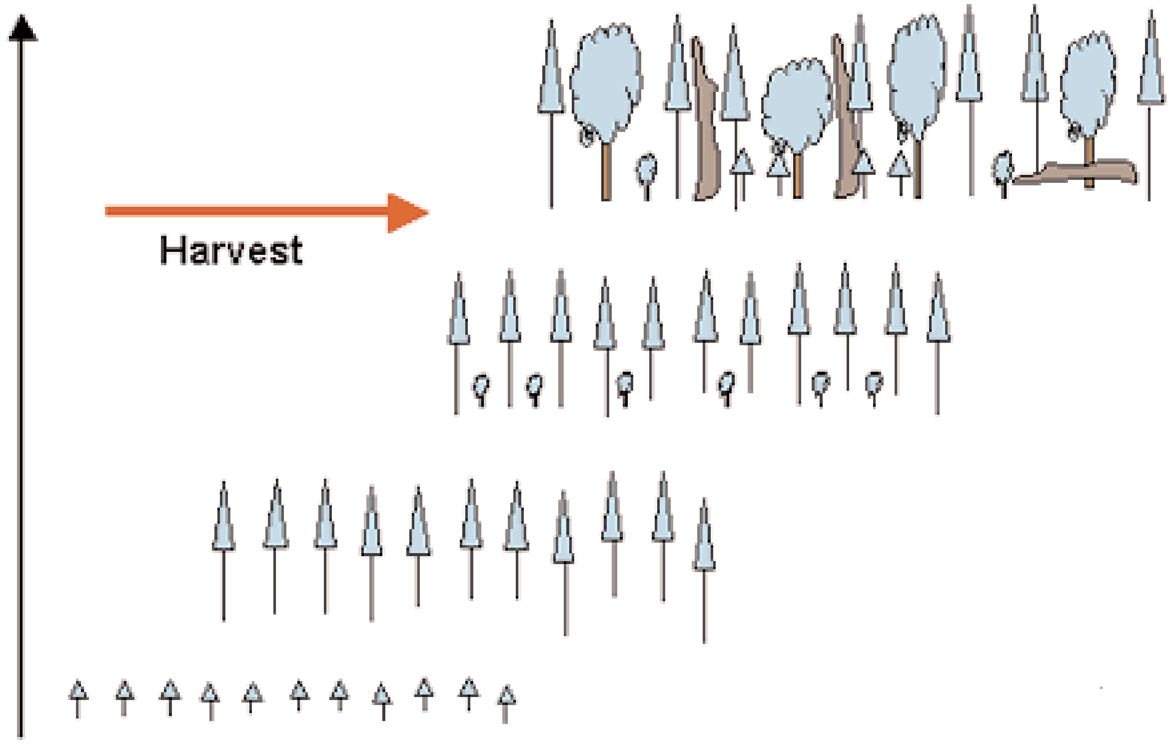



**Figure 4. Stylized representation of the development of structural complexity during stand development. In traditional forest managment, stands are harvested prior to significant levels of complexity developing.**

# Best Management Practices

# Best Management Practices

Forest management guidelines (often called Best Management Practices - BMPs) have been developed by various organizations to inform and aid forest management. These are typically site focused guidelines for a forest owner, forest resources professional, or logger, which describe how to operate (operational practices) in your forest to ensure sustainability and minimization of impacts.

The focus is typically on the forest and associated sensitive areas and their importance for wildlife and fisheries, water quality, and aesthetics. Also, general issues such as biodiversity are addressed here. In the Upper Great Lakes Region, most guidelines are voluntary in nature. They describe practices which minimize or mitigate against environmental impacts, as well as point out common practices which should be avoided.

Visit the North Central Region Forest Management Guides website to view and download Best Management Practices for Illinois, Michigan, Minnesota, and Wisconsin:

http://www.ncrs.fs.fed.us/fmg/nfmg/fm101/bmp/